University of Alberta Library
0 1620 3416241 0

For Reference

NOT TO BE TAKEN FROM THIS ROOM

SOME ASPECTS OF THE BITING FLY PROBLEM IN CANADIAN SUB ARCTIC REGIONS

Ex libris
universitatis
albertaensis

UNIVERSITY OF ALBERTA
QUAECUMQUE VERA

SOME ASPECTS OF THE BITING FLY PROBLEM

IN CANADIAN SUB ARCTIC REGIONS

Brian Hocking,
Department of Entomology.

University of Alberta,
September 1948.

Digitized by the Internet Archive
in 2018 with funding from
University of Alberta Libraries

https://archive.org/details/someaspectsofbit00hock

49
12

PREFACE

More accurately known as the bloodsucking rather than the biting flies, the insects dealt with in this paper include the mosquitoes, the blackflies or buffalo gnats, and the horse-flies and deer flies. Collectively these insects cause a great deal of discomfort to man over very large areas of Canada; they cause sickness and death in his domestic animals and birds, and sometimes even the death of human infants, and more rarely of adults.

The work recorded in this paper was carried out mainly during the springs and summers of 1947 and 1948, on behalf of the Defence Research Board of the Canadian Government Department of National Defence. The primary object was to provide information which would enable some mitigation of the nuisance of biting flies to personnel of the armed forces, and to others whose duties lie in regions heavily infested by these insects.

Both in 1947 and in 1948 a Canadian team of personnel from the Division of Entomology and from the Defence Research Board, and a U.S. team from the U.S. Bureau of Entomology and Plant Quarantine working on behalf of the Surgeon General, Department of the U.S. Army, were in close cooperation. Generous assistance was received from a great number of other persons and organisations at various times. While the present author was primarily responsible for all the work reported hereafter in detail*, for the sake of coherence and continuity brief reference has been made to work of other members of the parties. I would like to record my appreciation of the generosity of Mr. W.C.McDuffie and Mr. H.F.Cross of the U.S.Bureau of Entomology and Plant Quarantine in allowing me to refer to the as yet unpublished results of their work on mosquito larvicides and on repellent chemicals, and of Dr. C.R.Twinn of the Division of Entomology, Ottawa in permitting the use of data on the species and succession of species of mosquitoes and blackflies in 1947. Acknowledgements are also due to Dr. Alan Stone and Dr. Harold Morrison of the U.S. Bureau of Entomology and Plant Quarantine, to Mr.G.E.Shewell of the Division of Entomology, Ottawa, Professor E.B.Mains of the University of Michigan, Professor E.A.Steinhaus of the University of California, and Professor T.Petch of King's Lynn, England, to Professor E.H.Strickland, Professor E.H.Moss, Professor J.H.Whyte, Professor R.B.Miller, and Mr.E.Moore for assistance in the identification of specimens in their respective fields. Also to Professors L.A.Thorssen and G.W.Govier for assistance on matters relating to the measurement of stream flow and the flow of insecticidal fluids, and to Professor M.M.Cantor and Mrs P.A.Wight for the analysis of nectar samples; to the administrative staff of the military camp at Churchill and Mr.A.C.Jones of the Defence Research Board for countless services which I had no right to expect. Finally, and perhaps most of all, to each and every member of the Canadian and U.S. parties at Churchill in 1947 and 1948 for their unfailing cooperation at literally all times.

* With the exception of experiment 1 in 5.1.1, q.v.

C O N T E N T S

A B S T R A C T

ILLUSTRATIONS

A B S T R A C T

The species of blood-sucking flies of the families Culicidae, Simuliidae, and Tabanidae occurring in the vicinity of Churchill, Manitoba are listed. Some notes on the succession of species, larval habitats, and life histories of these species at Churchill are given, and some investigations into adult feeding habits, behaviour, and a new approach to the study of flight range are reported on. The influence of these insects on other organisms, and especially on man and his activities are considered in some detail. Experiments are described on the toxicity of some of the newer insecticides to all stages of mosquitoes in the field, and to the immature stages of blackflies under laboratory and field conditions. The possibility of utilising these materials for practical control measures is considered. Methods of personal protection from all three groups of insects are discussed and suggestions are made for improvements in these. 40 line drawings and photographs illustrate the text, and data are presented in 8 tables and 7 graphs. The paper concludes with 85 references, a selected bibliography, and appendices listing the birds of the area and describing equipment for the routine application of insecticides to streams.

1. THE CHURCHILL ENVIRONMENT

1.1. Climatic Conditions.

Churchill is situated at approximately latitude 59° N. and longitude 94° W., on the western shore of Hudson Bay, at the mouth of the Churchill River. It lies inside the Sub-arctic area, about 170 miles from its northern boundary.

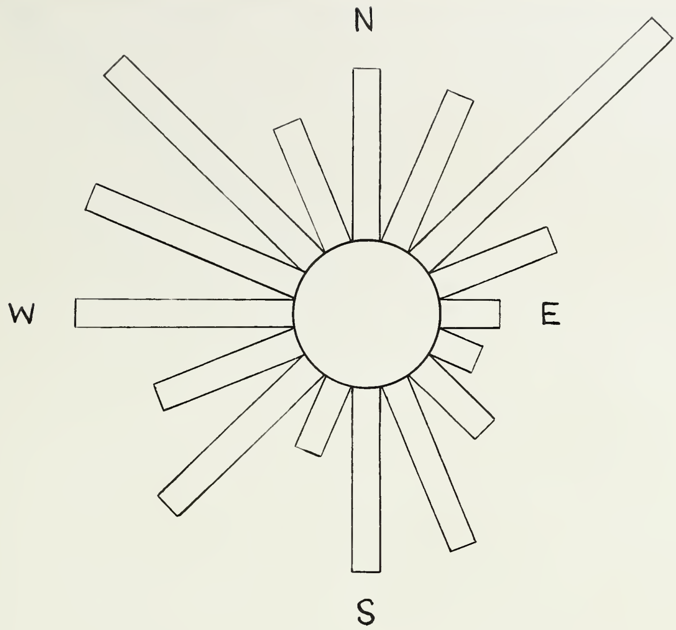
In winter Churchill is one of the coldest spots in northern Canada. The snowfall is light, and high winds off Hudson Bay prevent this forming much persistent snow cover, but cause drifting which may bury buildings. Very high wind chill figures are recorded, winds of 40 m.p.h. with temperatures down to -70°F being not uncommon. The summer weather however, may be unpleasantly hot and humid.

During the periods of entomological work at Churchill, daily weather summaries consisting of six-hourly readings of relative humidity, temperature, wind direction and speed, barometric pressure, and extent of cloudiness, and daily records of precipitation, were kindly provided by the Department of Transport meteorological officer. Supplementary records of special and local conditions in connection with specific items of investigation are given with the items to which they refer.

An analysis of the general weather records shows that the average temperature for the 87 day period from May 16 to August 10, 1947 was 47°F, the averages for May (part), June, July, and August (part) being 24.5, 44.8, 58.3, and 54.3°F

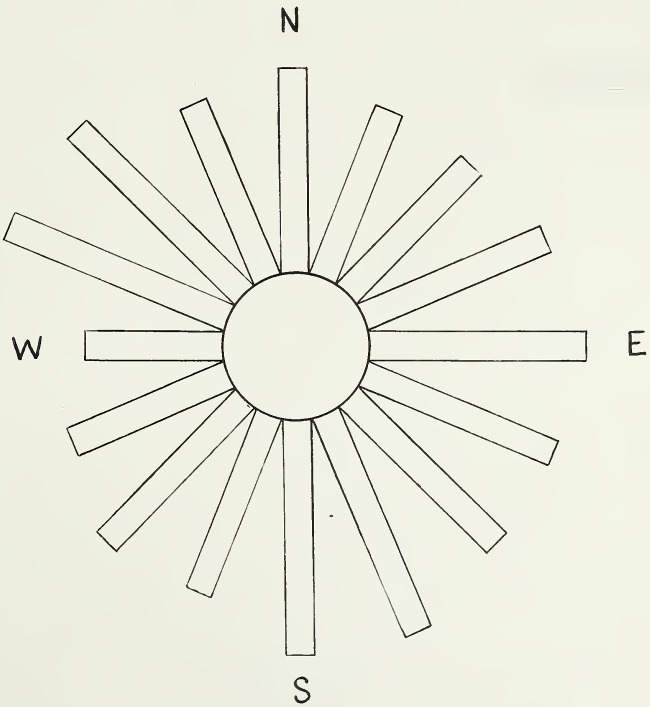
respectively. The range of temperature was 73 Fahrenheit degrees, from a low of 9°F on May 17 to a high of 84°F on June 20 and July 12. The relative humidity was high throughout the period, but particularly so before the thaw. The average figure for the whole period is 85.5 per cent; that for May (part) is 91.5 per cent and that for the remaining period separately 84 per cent. Relative humidity figures had a range of 57 per cent from a low of 43 on June 18 to 100 per cent on several days; daily averages ranged from 63 on June 19 to 100 per cent. No definite trends appear in the figures for barometric pressure.

Wind speed showed a slight general decrease from May to June and July, followed by an increase early in August. The average wind speed for the whole period was 12.6 m.p.h.; averages for each of the months separately were 14.3, 11.8, 11.9, and 14.7 m.p.h. respectively. The range of wind speed was from calm on May 18, July 13 and 16, and on August 3, to 45 m.p.h. on May 24 and 36 m.p.h. on August 6. The question of wind direction and the combination of this with wind speed has been treated in greater detail in view of the possible impact of these factors on the shift of insect populations, especially those of mosquitoes. Figure 1 shows the frequency with which the wind blew from each direction; apart from the scarcity of E and SE winds, there is no well marked trend although NE, and W to NW winds were somewhat more common. Figure 2 shows the mean wind speed for each direction; the scarcity of E and SE winds is to some extent compensated by their greater mean speeds. Figure 3 represents the product of mean speed and frequency,



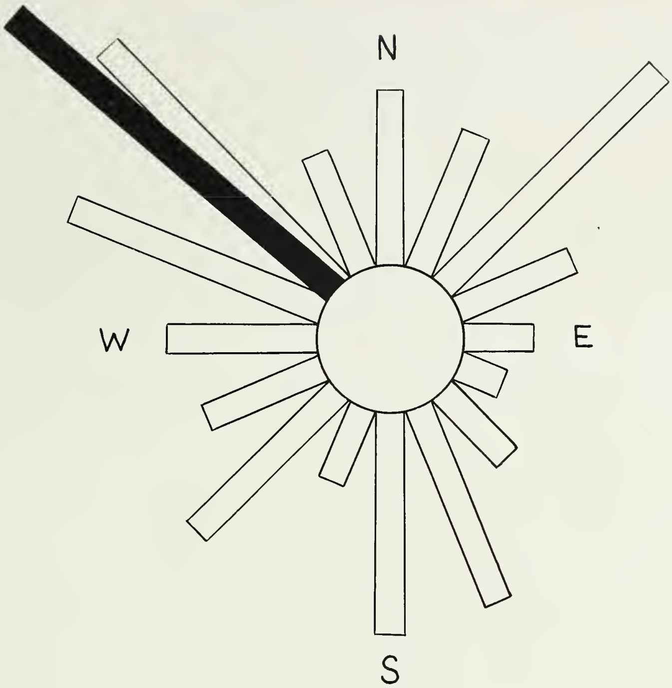
FREQUENCY OF WIND FROM EACH DIRECTION

Figure 1.



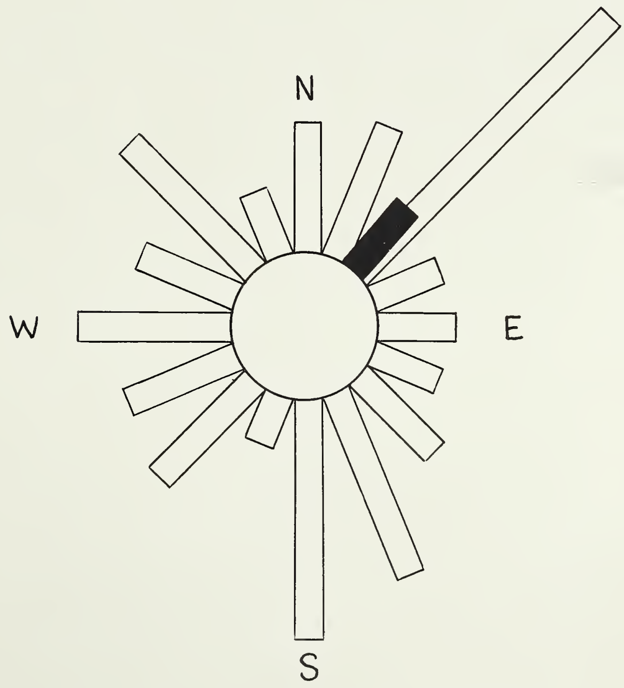
MEAN WIND SPEED FROM EACH DIRECTION

Figure 2.



TOTAL MILEAGE OF WIND FROM EACH DIRECTION

Figure 3.



WIND MILEAGE DURING MOSQUITO ACTIVITY

Figure 4.

and gives a picture of the general trend in the movement of air at Churchill throughout the whole period; the vector sum, representing a mean speed of 2.0 m.p.h. on a bearing of 311° (approximately NW), is indicated by the solid column. Figure 4 gives the same data as figure 3, but covers the period of significant adult mosquito activity only; from June 20 to July 20. There was a much clearer preponderance of NE wind during this period, but the vector sum represents a mean speed of only 0.15 m.p.h. on a bearing of 39° (approximately NE).

The total precipitation during the period was 5.18 inches water equivalent, of which 0.08 inches was in the form of snow. This precipitation was distributed between the four months as follows: 0.18, 0.91, 0.95, and 2.90 inches, the maximum rainfall on any one day being 1.63 inches on August 5. There was measurable precipitation on 36 of the 87 days; on seven of the 16 days in May, ten days in June, 12 days in July, and seven of the ten days in August.

Observations of cloud conditions during the hours of daylight may be summarised as follows: 53 per cent overcast, 40 per cent partly cloudy, 7 per cent clear.

The ice went out of the Churchill River on June 20 1947; the expected date for this occurrence being that of the spring tides closest to June 15 (5), the season at this stage was nearly a week later than normal. A comparison of average temperatures for June and July of this year with similar averages obtained over a number of years (6) supports the impression obtained from residents that by the end of July the

season was normally advanced.

Weather data for 1948 are still accumulating so that a complete analysis is not yet possible. The season was very much earlier to start with, but cold weather early in June retarded development until by early July conditions were comparable with those obtaining at this time in 1947 although very much drier.

1.2. Other Ecological Conditions.

Within a radius of a few miles of Churchill is to be found a great variety of terrain, including spruce-larch forest, muskeg, tundra, tundra-meadow, birch-willow scrub, low limestone-gravel and granite ridges, tidal flats, and sand dunes. It is a zone of transition from forest to tundra and supports a varied insect fauna including species of biting flies typical of the forest and of the plain and of the sub-arctic and the arctic.

The northern fringe of the sub-arctic forest extends to within a short distance of Churchill. In this region it is rather open and swampy and consists chiefly of stunted trees rarely exceeding 30 feet. The forest floor is for the most part soft and spongy underfoot, very tiring to walk on and often treacherous to the unwary.

The tundra and tundra-meadow in the area extends from the scattered tree growth along the uneven margins of the forest

to the shore of Hudson Bay. The predominant vegetation consists of lichens, coarse grasses and mosses, but other flowering plants also abound, their successive blooming adding a touch of colour and beauty to the otherwise rather bleak landscape. Where soil conditions are favourable, dwarf spruce grow singly or in small clumps. In exposed situations overlooking Hudson Bay the branches of these trees grow out only on the south side of the trunk; or the whole tree may have a prostrate form, spreading out in a mat a few inches above the surface of the rock as if to take full advantage of the meagre heat reflected from this. In protected situations such as along the borders of streams, dwarf birch and willow grow, in places forming dense thickets.

Large numbers of aquatic and wading birds nest and raise their young in the marshes and swamps of the Churchill region. Common among them are ducks, geese, gulls, terns, sandpipers, plovers, curlews, and ptarmigan. Among them, too, is that familiar habitué of suburban gardens, the American robin. Mammals are much less in evidence. A few caribou were seen near the Churchill River and along the shore; also two porcupine in the forest and a number of larch trees stripped of bark by their feeding. Burrows and trails of small rodents are numerous, but their numbers were at a low ebb in 1947 (14,52), the animals themselves were rarely seen and, in spite of several attempts to trap them, only three lemming were captured. From these, 2 males and 6 females of the flea Megabothris groenlandicus Wahlgren were taken (det. G.P.Holland). In 1948 mice and lemming were more numerous, and rabbits and the fresh tracks of wolves were

seen. Schools of white whales enter the mouth of the Churchill River after the ice goes out, and numbers of these are killed for their meat and oil by local Indians and trappers. Of fish, pike, grayling, and suckers abound in the larger streams and serve as a major part of the diet of sled dogs during their enforced summer idleness, as well as being preserved for winter use. Sticklebacks were much more numerous in 1948 than in 1947. No reptiles were seen, but frogs were common in the marshes, and specimens collected were identified by C.L.Patch, of the National Museum, Ottawa, as the northern wood frog, Rana sylvatica cantabrigensis.

Drainage is generally poor in the Churchill region because much of the terrain is low-lying and the ground is permanently frozen a short distance beneath the surface. As a result, innumerable shallow pools form on the tundra and in the forest during the spring thaw and serve as breeding places for the countless hordes of mosquitoes that appear on the wing in late June and July. What drainage there is occurs largely through numerous streams that flow into the Churchill River or into Hudson Bay. From these streams and from the rapids of the river, vast numbers of blackflies emerge and, with the mosquitoes, and the bloodsucking tabanids that develop in the forest, plague man and beast throughout the short summer.

The biological violence of this short summer is a most striking feature, to one accustomed to the living continuum of the tropics, and can perhaps be conveyed best by a rapid survey of the sequence of events as observed in 1947.

The conspicuous insect life at the end of May

consisted of springtails on the melting snow and ice, sometimes in such abundance on trails that they are reported to impede the passage of sleds, and various small flies, mainly dolichopodids and mycetophilids on the surface and at the margins of pools.

By June 5 the smaller streams were beginning to flow, although ice remained at the bottom. Stonefly nymphs, previously solidly frozen, were active inside pockets of water formed inside blocks of ice presumably by radiation absorbed by their own dark bodies. Pools at this time contained many chironomid and dytiscid larvae and gerrid nymphs, and birds were courting on the marshes. Flowers of the mountain saxifrage, Saxifraga oppositifolia, the first plant to be found in bloom were collected on June 15, and by this time dung flies and bumble bees were flying, and most birds were sitting on eggs.

By June 22, larch, willows and birch were coming into leaf, and many ericaceous plants, especially species of Ledum, Rhododendron, and Andromeda were flowering. Chironomid adults were locally numerous, and well grown caddis larvae abundant in pools and streams.

The first week of July brought out the first families of ducklings and ptarmigan, many more plants were newly in flower, the sweet coltsfoot, Petasites sp. conspicuous amongst them, and arctic heather, Dryas integrifolia, several times as abundant as any other flower. Among insects adult dragonflies and caddis flies were on the wing.

The replacement of arctic heather by cotton grass, Eriophorum sp., as the most abundant flower marked the middle

of July; by this time the eggs of plovers and terns had hatched, and half grown tadpoles were to be found in many of the pools. Most groups of insects were represented by the adult stage, those recently emerged including several species of mayflies, weevils, and some syrphid and trypetid flies.

By the third week of July the peak of adult insect activity was over, and the eggs of a great many species were to be found in, and at the verges of, the now much diminished pools and streams. The ox-eye daisy, Chrysanthemum arcticus, and the conspicuous fireweeds, Epilobium spp., were coming into flower, the latter becoming extremely abundant.

An excellent account of the invertebrate ecology of Churchill is given by McClure (38).

2. THE SPECIES AND SUCCESSION OF SPECIES OF BITING FLIES AT CHURCHILL

2.1. The Mosquitoes (Culicidae: Diptera).

Eight species of Aedes and two species of Culiseta have been identified among the specimens collected or reared in the Churchill area during 1947. No other genus of the sub-family Culicinae was represented, but the predaceous larvae of three genera of non-biting mosquitoes of the sub-family Chaoborinae, namely, Eucorethra, Mochlonyx and Chaoborus, were fairly common in the Culicine breeding pools. Unfortunately, none were reared to the adult stage, but a male and a female collected from a mating swarm at 4 p.m. on July 24 belonged to the species Chaoborus nyblaei Zett.

The two species of Culiseta represented are C. alaskaensis Ludl., and C. impatiens Wlk. They are not abundant in the area, only small numbers of overwintered females being seen or captured during the month of June. No males or aquatic stages of the species were found.

The species of Aedes definitely determined include A. nigripes Zett., A. punctor Kby., A. nearticus Dyar., and A. communis Deg., occurring probably in that order of abundance; A. campestris D.&K., and A. excrucians Wlk., less abundant, but numerous and widespread; A. flavescens Müll., and A. cinereus Mgn., relatively few and localised in occurrence.

In 1948 several further species of Chaoborinae were taken. Males and females of Mochlonyx culiciformis DeG. were

reared from pupae collected in the forest on July 17. Other material has yet to be identified and may contain new species. The larvae of Culiseta alaskaensis were collected and reared to maturity in a field insectary.

In the genus Aedes two species were recorded for the first time in 1948. These were Aedes fitchii Felt & Young, and A. spencerii Theo., neither of them common, but the latter taken in most interesting circumstances. Only three specimens were taken, all of them inside army vehicles at the beginning of June, well before any other species of the genus had emerged at Churchill either in 1947 or 1948. The weather at this time was unusually warm, and winds had been continuously SSE at speeds up to 22 m.p.h.; immature stages of A. spencerii have never been taken at Churchill. It is most probable that these specimens came in from further south, either wind borne, or on aircraft or trains. The fact that the vehicles in which they were taken were all within easy access of both the airport and the railway station, suggests the latter explanation. A. specerii is known to be a migratory species, and data on the northern limits of its breeding would be very interesting.

Immature stages of A. cinereus were taken for the first time in 1948, collected in the forest 12 miles south of Churchill. Matheson identified A. nigromaculis Ludl. among the mosquitoes collected here by McClure in 1936-7, but no specimens of this species have been obtained.

All the species of Aedes found in the Churchill area overwinter in the egg stage. In 1947 larvae began to hatch out in small numbers in snow pools in sheltered places on the

tundra at the beginning of June, when snow and ice were still prevalent in the area. By the middle of June, when the snow was largely gone from the open country, the larval population of several abundant species was nearing its peak in pools in the open and among the sparse tree growth along the margins of the forest. These species were A. nigripes, A. punctor, and A. nearcticus. Early stage larvae of A. excrucians had also begun to appear. In the forest the first larvae of A. communis were found hatching in favoured snow pools on June 9, when nearly two-thirds of the forest floor was still covered with fast-melting snow.

Pupation of A. nigripes began on June 16, and A. punctor on June 17, the first adults emerging on June 20, and June 21, respectively. Emergence of A. nearcticus started on June 22, and that of A. communis in the forest on June 24. Periodical collections indicate that these four dark-legged species are the dominant ones in the Churchill region.

Towards the end of June emergence was general. During the early part of July pupae were still common, but larvae were becoming increasingly hard to find. By July 3, tremendous numbers of mosquitoes were on the wing, and they continued to increase until a peak of abundance was reached during the second week of July (Fig. 5). The pest species were augmented by adults of A. campestris on July 5, A. excrucians on July 9, A. cinereus on July 13, and A. flavescens on July 20. By the third week of July, however, a definite falling off in abundance and aggressiveness of the mosquito population was apparent, and by early August, their numbers had reached relatively small proportions.

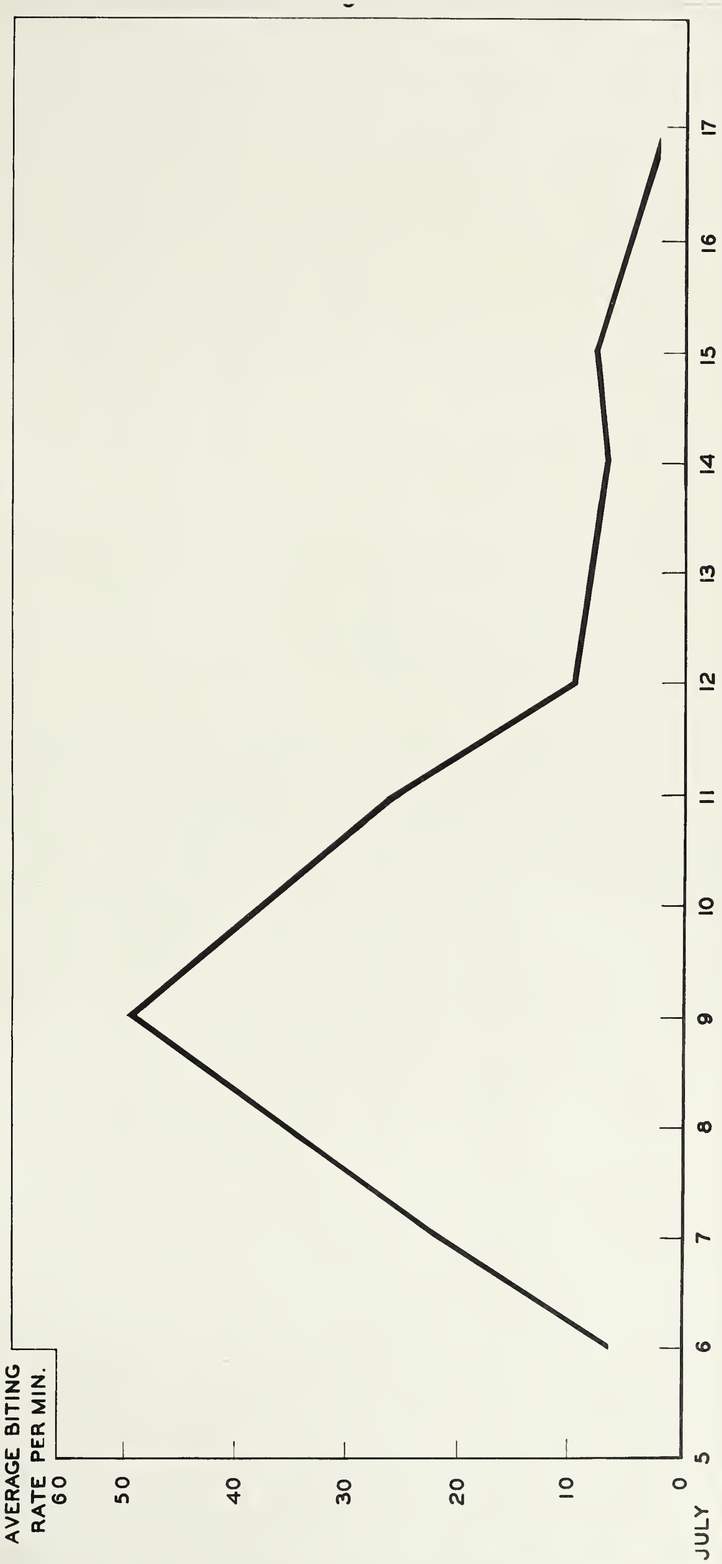

AVERAGE BITING RATE OF MOSQUITOES
CHURCHILL
JULY 1947
AVERAGE BITING RATE PER MIN.
60
50
40
30
20
10
0
JULY
5
6
7
8
9
10
11
12
13
14
15
16
17

Figure 5.

The adult females of the four common species A. nigripes, A. nearcticus, A. punctor, and A. communis, are difficult to separate without associated males or last larval exuviae, which makes specific biological observations difficult, especially late in the season when much of the vestiture of scales has been lost. The first two species are rather hairier and are characteristic of the tundra; the last two smoother and typical forest species. A. punctor, however, is more mobile, and hence more often found in the open than is A. communis, which at least when newly emerged tends to remain very close to its larval habitat (62).

Typical specimens of A. nigripes are much larger than those of A. nearcticus and have a relatively longer proboscis, the ratio of proboscis length to wing length being about 0.84 in the former and only 0.73 in the latter. The occasional specimens of A. nearcticus which have small sub-lateral patches of white scales on the mesonotum can be identified at once in the field. The ratio of proboscis length to wing length in A. punctor is 0.7 and in A. communis 0.64; typically, the former can be recognised by the lateral expansions of the basal bands of white scales on the abdominal terga, and by the tendency of the black scales on the venter to form a median stripe instead of transverse bands as in typical A. communis specimens. A. communis sometimes develops in incredible numbers in quite small woodland pools. Adults emerging from these pools are much smaller than normal, presumably as a result of severe overcrowding in the immature stage. It is interesting to note that Mellanby (40) reports A. punctor as overwintering

in the larval stage at latitude 69°N in Finnish Lapland.

A. cinereus is a small, dark mosquito of the forest, the smallest in the Churchill fauna, and the only distinctive black-legged species. It is late emerging, non-migratory, and has a rather short proboscis.

A. campestris, the commonest of the species with the tarsal segments ringed with white scales, is a most attractively marked mosquito with its mixed black and white scales on the wings, bottle green eyes, and well marked pattern of almost silver and gold scales on the mesonotum. Late in the season in 1947 this species was more troublesome than any other in the military camp itself.

A. excrucians is next in abundance to A. campestris. It is a large dark distinctive mosquito, late emerging, and according to Hearle (26) does not travel far from its breeding grounds.

A. flavescens, a large yellow species, with white banded tarsi, is a late appearing mosquito, individually conspicuous, but of comparatively minor importance. Its life history is fully dealt with by Hearle (27). In 1948 this species put in a rather unexpected early appearance before the end of June, after which there was an interval of nearly two weeks during which no specimens were taken, before it reappeared about the middle of July. This would suggest that under certain conditions of rainfall the larvae may hatch out in two broods.

Culiseta alaskaensis and C. impatiens are large mosquitoes with white banded tarsi and black spots on the

wings; alaskaensis having the more distinct wing spots, and being the largest mosquito in the Churchill fauna. These species both overwinter as adults and are consequently the first mosquitoes to appear in the spring, flying and biting some two weeks before the earliest species of Aedes emerge. Dr. Douglas Leechman of the National Museum, Ottawa, quotes an entry in Peter Fidler's Journal for April 4, 1792, which may be taken to refer to a species of Culiseta. This entry, which reads as follows, was made near Fort Fitzgerald, northwest of Lake Athabaska, just south of the northern boundary of Alberta:

> "Put up about ½ mile above the head of the rapids amongst a deal of old Large Poplars we made a good fire & soon after we were all very much surprised to see numbers of muskettoes flying about altho the Snow was more than 10 inches deep on the ground every where on examination we found that betwixt the Bark of the Poplars and the tree, of the old Dry wood there was a large open space which was full of muskettoes that have been in that situation all winter in some places they was in large cakes of 2 Inches thick the heat of the fire had invigorated them so as to be able to fly about in the manner before mentioned"

2.2. The Blackflies (Simuliidae: Diptera).

Previous to 1947, blackflies had been collected at Churchill in 1934, by A.M.Heydweiller, and in 1936 by H.E.McClure. These collections were examined and identified by Twinn.

Heydweiller's collection, all females except where otherwise indicated, included six species which are listed as follows, together with a statement of the numbers of specimens and the period during which they were collected:

Simulium venustum Say, 121, July 11 - Aug.30

S. vittatum Zett., 34 (plus 4 males) July 8 - Aug.15

S. ottawaense Twinn, 26, July 10 - Aug.15

S. arcticum Mall. 4, July 30

S. perissum D.&S., 4, July 30 and Aug.11

Eusimulium baffinense palens Twinn, 2, July 30.

McClure's collection was made up of many hundreds of female specimens, mostly *S. venustum* and *S. vittatum*, but also including four specimens each of *S. arcticum* (July 11 - 23) and *E. subexcisum* Edw. (July 11).

Thus these two collections were comprised of seven species. Among the specimens collected or reared during 1947, eight species are represented, five of them being additional to those collected by Heydweiller and McClure. The eight species taken in 1947 are as follows:

Simulium venustum Say

Simulium vittatum Zett.

Simulium sp.

Eusimulium aureum Fries

Eusimulium latipes Mgn.

Eusimulium species A.

Eusimulium species B.

Eusimulium species C.

During 1948, at the time of writing all species taken previously had been collected as adults or reared from collected pupae except S. arcticum, and E. baffinense palens. In addition several specimens resembling E. boreale Mall., specimens of what appears to be another new species, close to S. venustum, and the first male specimens of E. aureum were taken, making a total of 14 species collected in this region.

The fact that no pupae or male specimens of S. arcticum have been taken suggests that this species, like Aedes spencerii, is unable to overwinter at Churchill, but migrates in from breeding areas to the south and west. This species is noted for appearing sporadically in very large numbers at almost incredible distances from its breeding grounds (46).

Simulium venustum is the most abundant of the black-flies in the Churchill area and the most important pest of man. The immature stages were found in all bodies of running water examined wherever blackflies were developing, including drainage ditches, rills, larger streams, and rivers.

The first pupae were discovered in 1947 on July 3, in a small stream in the camp area and adults commenced emerging on July 5. Observations on several other streams indicated that emergence was general in the area on this and subsequent days. Females were first captured attacking humans on July 8, by which date mosquitoes were reaching their peak. By mid July,

the numbers of blackflies of this species were tremendous, especially in wooded areas, and the streams contained heavy infestations of eggs, larvae, and pupae, a condition that persisted until early August, when observations ceased.

Further south, S. venustum passes the winter in the larval stage (60) but in the Churchill region it is believed to overwinter in the egg stage, except possibly in the Churchill River, which continues to flow all winter beneath the ice. The smaller streams were frozen solid in the winter of 1946-7 and thawed out during the first week of June. At this time small numbers of dead pupae and cocoons of S. venustum from the previous season were found attached to stones and to vegetation in several of the streams, but no living pupae or larvae were seen, and young larvae did not begin to appear until after the middle of June, two to three weeks before the first adults of this species were on the wing.

There appear to be at least two generations of S. venustum at Churchill and probably three or a partial third, the generations overlapping, so that after the first adults emerge all stages may be found together throughout the short summer season. Apparently development continues until the streams freeze up. According to an official of the Churchill grain elevator, adult blackflies are present until the snow flies.

Female specimens of S. vittatum were collected east of the Churchill River, in the open, and in the woods south of Churchill on June 21, 1947. These were the first blackflies on the wing, and presumably developed from larvae

that had overwintered in the rapids beneath the ice in the Churchill River. The ice went out on June 20. Pupal skins of this species were found on submerged rocks in the rapids close to the shore line, at Mosquito Point, on July 9. The pupae were not found in any of the numerous smaller streams examined.

Edwards identified material reported by Longstaff (72) as attracted to, and apparently biting man in enormous numbers at latitude 64° 40' N on the west coast of Greenland, as this species. There was no evidence of this species attacking man at Churchill.

The material referred to as Simulium sp. consisted of two pupal cases in cocoons collected on a stone taken from the Churchill River rapids at Mosquito Point on July 9. The cocoons are boot-shaped, and the respiratory tufts of the pupae are short and comprised of 16 filaments. The material may represent an undescribed form.

Eusimulium latipes was found in 1947 in a shallow, stony, rather swift little stream that has its source in a pool in the camp area and flows through open woods and marshy meadows towards the Churchill River. Numerous well-grown larvae and small numbers of pupae were found on stones and grasses in the stream on July 3, and were the first blackfly pupae seen in the area. In 1948 specimens were obtained from a variety of smaller streams. This species, which is widespread in Europe was first recorded in North America near Hull, Que., by Twinn (60). It apparently has only one generation a year.

Six females of Eusimulium aureum were collected on

July 24 and 25, and August 2, 1947, but no pupae were found. In 1948 specimens were taken throughout the later part of the season and in various localities. This attractive species is widely distributed in North America.

Both sexes of Eusimulium species A were obtained from pupae taken from three streams, two draining into Hudson Bay and one into the Churchill River. Emergence of adults was actively proceeding from one of these streams on July 6, and may have commenced a day or two earlier, as on this date empty pupal skins greatly outnumbered pupae. Newly emerged specimens were crawling up the vegetation in large numbers and many of the flies were also on the wing. Emergence of this species from the other two streams was still in progress about a week later, and females were taken on the wing on July 25. This is apparently an undescribed species; the pupa has short, bushy respiratory tufts, each consisting of 25 - 30 filaments, arranged mostly in pairs on short stalks arising from a common base. The cocoon is of indefinite shape.

Pupae and pupal cases of both sexes of Eusimulium species B were taken from Goose River on July 8 and from stones in the Churchill River rapids at Mosquito point, on July 9. one pupa was found in collections from Eastern Creek on July 12.

Eusimulium species C is represented by one female which emerged by July 12 from a pupa collected on July 6. The respiratory tufts of this pupa each consist of numerous filaments (30 - 40) branching out on short stalks from the dorsal surface of a stout elongate main trunk. Further material of these species was obtained in 1948.

2.3. The Horseflies and Deer flies (Tabanidae: Diptera).

Only a relatively casual survey of this group of insects was possible, the study taking second place to that on mosquitoes and blackflies and to control experiments on these two groups. The material obtained in 1947 consists of specimens collected during the course of that work, and is comprised entirely of adult females, no males or immature stages being taken.

These specimens represent five or six species of the genus *Hybomitra* and four species of *Chrysops*. These species, arranged within the genera in order of abundance are: *Hybomitra affinis* Kby., *H. septentrionalis* Loew, *H. metabola* McD., *H. zonalis* Kby., *H. hearlei* Philip, and *H. gracilipalpis* Hine; and *Chrysops carbonaria* Wlk., *C. furcata* Wlk., *C. nigripes* Zett., and *C. frigida* O.S.

The succession and relative abundance of these species as indicated by the material available are shown in figure 6. The first specimens taken were *H. metabola*, collected on July 5. Three independent reports were received of men being bitten prior to this (July 3) by flies which, from their descriptions, could have been tabanids. The first specimens of *H. affinis* were taken on July 6. This rapidly became the dominant species, and remained so until the middle of August (when observations were terminated) although in close competition with *H. septentrionalis* from the third week of July onwards.

The earliest species of *Chrysops* to appear was

THE SUCCESSION AND RELATIVE ABUNDANCE OF TABANID SPECIES AT CHURCHILL

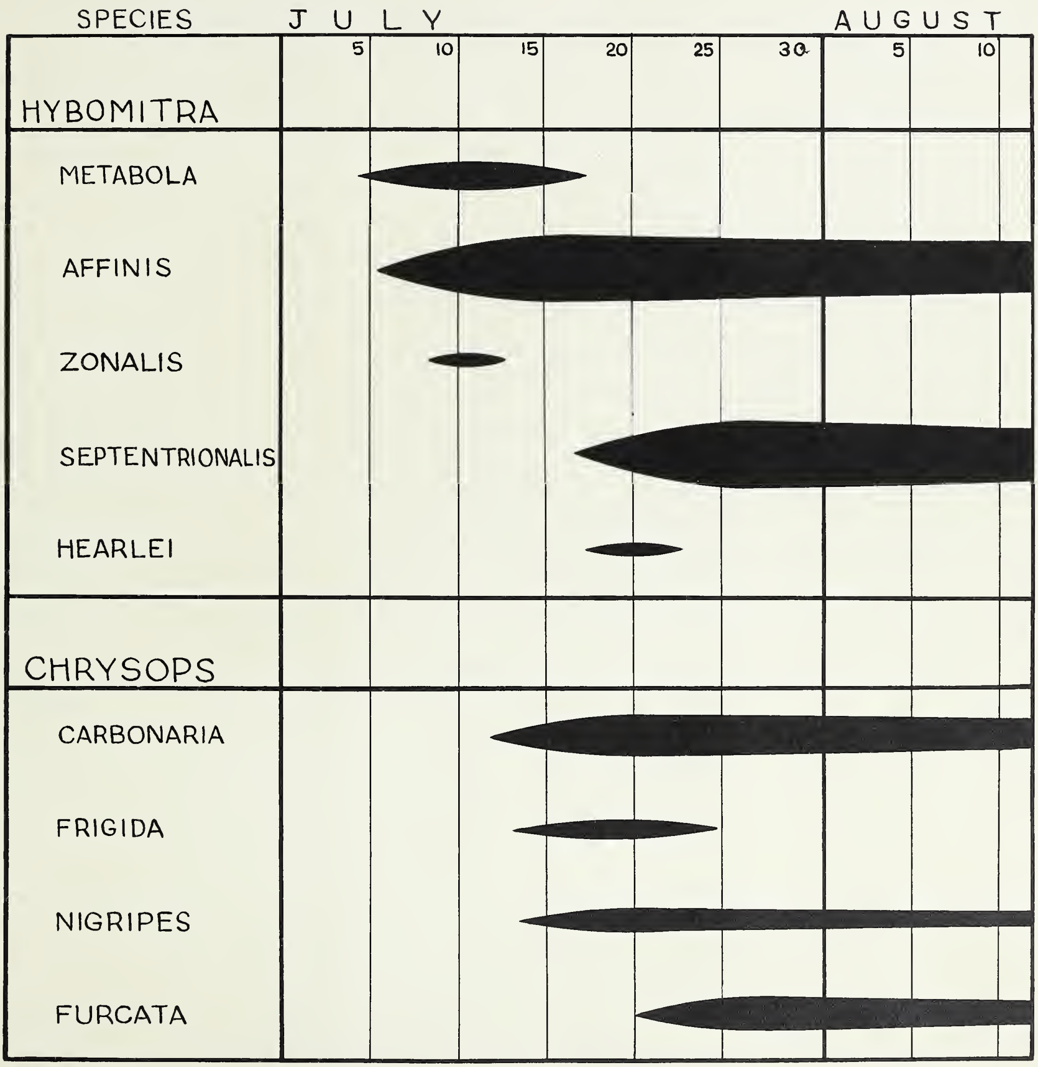


Figure 6.

C. carbonaria which was first taken on July 12. This was the most abundant species of the genus until towards the end of July, when it gradually gave place to a predominance of _C. furcata_, which, with _C. frigida_ and _C. nigripes_, made its first appearance a few days after _C. carbonaria_.

Hybomitra zonalis with its striking yellow and black abdomen was remarkable in that it put in an early appearance on July 10, but was not taken again thereafter. All the specimens of this species were collected in the camp area.

In 1948, all the species taken in 1947 were again recorded, and in addition the tabanine species _H. sexfasciata_ Hine, and a species close to _H. hinei_ Johnson; and the pangonine species _C. mitis_ O.S. Only two or three specimens of the first two species were taken, but _C. mitis_ was found to be quite abundant late in the season in the forest 25 miles south of Churchill. Many males were collected, including those of _H.gracilipalpis_, taken in copula, and one specimen believed to be _H. septentrionalis_; the male of this species has not yet been adequately described. A number of larvae were also collected and are being reared. _H. zonalis_ was much more abundant in 1948, and several specimens were taken as late as July 24, in the forest 25 miles south of Churchill.

Dr. H.H.Schwardt identified _H. illota_ O.S. and _H. rhombica_ O.S. among the material collected at Churchill by McClure in 1936 and 1937. No specimens of either of these species have been taken in this work.

2.4. Other Biting Insects.

Apart from the three families already dealt with, the only group of blood-sucking flies of any potential significance at Churchill is the family Heliidae (Ceratopogonidae). These insects are commonly known as the biting midges, or no-see-ums, and present a somewhat different problem to the previous groups, since their extremely small size permits them to penetrate the ordinary protective nets and screens.

In 1947 no-see-ums were very scarce and only three or four specimens were secured. In 1948 they were much more numerous, and in a really favourable year, they might well be quite troublesome. Several species of the genus Culicoides were taken, but have not yet been identified; the taxonomy of the group is difficult, and has received very little attention.

No species of the family Rhagionidae, the snipe flies, has been recorded biting man at Churchill. One member of the 1948 party however received a significant bite from a spider while in a forested area.

3. OBSERVATIONS ON THE BIOLOGY AND BEHAVIOUR OF THE BITING FLIES

This is a subject on which, at first sight, very little progress seems to have been made; the difficulty however, is a very natural one. As soon as the observer enters the habitat of biting flies which use man as a host, the whole attention of all of these flies is directed towards obtaining the much sought after meal of human blood. The activities on which observations are required cease abruptly, and the would be observer becomes himself the object of observation. No progress can be made with eliminating this difficulty until more is known of the factors which attract these insects to their hosts. As a result, most of the data obtained will have to be based on circumstantial evidence, except for that relating to blood meals from man.

3.1. The Mosquitoes.

3.1.1. Immature Stages:

The eggs of most species of *Aedes* will withstand dessication and extreme cold, and as a general rule will not hatch until they are flooded with water after having been subjected to these conditions. Roubaud (78) and Gjullin et al (67) have demonstrated the importance of chemical stimuli in the hatching of the eggs of species of *Aedes*. More recently

Abdel-Malek (1) has shown that eggs of A. trivittatus require the presence of certain plant hormones in critical concentration for optimum percentage hatch. Eggs of Churchill species of Aedes have been observed to hatch in the laboratory when flooded with water from tundra pools, but no work with specific plant hormones has yet been done on these.

Only few isolated observations on the behaviour of larvae and pupae have been made, the period of larval abundance being largely occupied with work on chemical control measures. In addition to the normal wriggling method of locomotion characteristic of mosquito larvae, the larvae of A. excrucians have been observed in water flowing very slowly through a drainage ditch, to maintain their positions in this ditch with no apparent locomotory movements. Observations on the intervals between submergence and surfacing for this species have been made as follows: at the surface, 2, 2, 26, 3, 6, 2, and 4 seconds; submerged, 10, 123, 343, 8, 24, and 32 seconds. In general a long period of submergence was followed by a long period at the surface.

In muskeg areas, where ground movements may spread out many yards from every step taken, it was found impossible to approach pools without sending all larvae to the bottom, and the least movement while observing larvae from the margin of a pool would interrupt their activities. A conspicuous feeding habit, especially among tundra species, consists of grazing along the edges of decaying grasses in the pools. The microflora and fauna of these grasses are being studied.

It is of some interest to record that larvae

isolated in the insectary for individual rearing to associate last larval exuvium with adult, were invariably slower to mature than comparable larvae which were reared together under otherwise identical conditions.

The larvae of the chaoborine species appear to be the most important predators on Aedes larvae, consuming large numbers of these in the insectary. These predators also feed on fairy shrimps, and are in turn fed upon by the larvae of dytiscid beetles. A fairy shrimp has been taken from the prehensile antennae of a Chaoborus larva which was itself held in the mandibles of a larval dytiscid.

3.1.2. Emergence and Mating:

In insectary rearing, mortality at emergence is considerable, and is higher among females than among males. The reasons for this are unknown, but contributary factors may be the unnatural amount of illumination from the sides and below; perhaps the abnormal stimulation of the pupa to activity which is difficult to avoid during collection and transportation, has a devitalizing effect.

The first interest of the newly emerged adult of all Churchill species of Aedes appears to be mating. This takes place shortly after emergence, and no species has been known to take a blood meal before mating. The typical mosquito mating swarm has been observed for most species, and these observations follow:

A. nigripes at 1.15 p.m. on July 3, 1947, over the

tundra between a narrow belt of scrubby spruce, and the camp buildings. The mosquitoes occurred in dancing clouds around the perimeter of a small shallow lake, the swarms extending about 3 - 9 feet above the ground.

A. punctor a few feet above the Hudson Bay Railway tracks, in the forest near Warkworth Creek, after sunset (10.30 p.m.) on July 13, 1947. Also over the tundra near woods east of Churchill, at 4.0 a.m. (ten minutes after sunrise) on July 25, and also in 1948, together with -

A. communis forming one enormous swarm stretching as far as the eye could see as a dark cloud over the Hudson Bay Railway track at Warworth Creek, and following round the bend in the track. This swarm persisted from 8.30 until 9.0 p.m. on the evening of July 16, all individuals heading in the same direction at any one time, sometimes north and sometimes south, but always along the railway track, and extending from a height of 3 - 10 feet. There was no wind at this time; the air temperature over the track was 62^{o}F, that over the vegetation on either side 58^{o}F; saturation deficiency decreased from 4.3 to 3.7 mms. of mercury, and light intensity remained at about 650 lumens per square foot. Cloud was 4/10ths, and the sun set at 9.45 p.m.

A. excrucians over open tundra at 9.30 p.m. on July 12, temperature 61^{o}F, saturation deficiency 2.5 mms., wind speed 5 m.p.h., light intensity 90 lumens p.sq.ft.

A. campestris in rather small swarms over a forest clearing at Warkworth Creek, at a height of 6 - 12 feet at 8.30 p.m. on July 16, 1948. Weather data as in note on A. communis.

Further evidence of the remarkable temperature sensitivity shown in these notes was obtained 2 hours after sunrise on July 17, when both mosquitoes and blackflies were seen to select the charred vertical surfaces of tree stumps in a burnt off area as resting sites. The greater absorption by these surfaces had raised their temperature 2 Fahrenheit degrees above the normal tree trunk.

3.1.3. Adult Feeding and Activity:

Mosquitoes having mated, man has no longer any practical interest in the male mosquito, but becomes increasingly interested in the female. It is well established that many mosquito species can lay viable eggs without a blood meal (9,30,50), although the number may be reduced, and this is probably true for most of the Churchill species. Certainly, as the season progresses, the majority of the mosquitoes which are attracted to man are carrying eggs of some description, although it is unlikely that many of them have fed on blood. Attempts were made in 1948 to obtain mosquitoes freshly fed on the blood of animals other than man for precipitin tests; no such specimens were secured up to the end of July. A list of birds and mammals seen in the area is given as appendix A; except for the white whale, the mammals are all exceedingly rare during the fly season, the commonest being mice and lemmings which spend most of fly time either under ground, or in water. There is no evidence that the cycle of lemming abundance is reflected in mosquito abundance. Nestling birds, and the few amphibia have been watched, but mosquitoes have not been seen to

feed on these; again, possibly because the observer is preferred. Longstaff (72) reports A. nigripes feeding on the redpoll and perhaps the arctic hare in Greenland, and Thienemann (83) records A. punctor and A. communis apparently feeding on Microtus and lemmings.

In most individuals of all mosquito species collected on July 17, 1948, development of the eggs had scarcely begun; in one specimen of A. campestris eggs could be detected, and in one of A. communis about 50 developing eggs could be counted in each ovary. Further dissections on July 26 revealed considerable progress in development, although eggs were still far from ready to be laid. A total of 170 eggs could be counted in specimens of A. punctor, and 300 in A. excrucians. Captive specimens of A campestris, given a blood meal in the insectary a few days previously, laid eggs on wet cotton on July 25 and 26.

Nectar feeding appears to be a universal habit in Churchill mosquitoes, and here, circumstantial evidence has been kind. The very common woodland orchid Habenaria obtusata Pursh., as previously reported by Raup (45), is apparently normally pollinated by mosquitoes, which pick up one or both of the pollinia adhering to the ventral margins of the eyes, when visiting mature flowers, presumably for nectar. On July 24 and 25, 1947, 6 per cent of mosquitoes were found to be carrying the pollinia of this orchid. A larger sample collected on July 12,13,16 and 17, 1948, gave the following figures: total mosquitoes, 1364; number carrying a single pollinium, 55; number carrying two pollinia, 3. It seems

feed on nectar [illegible], possibly because the [illegible] is [illegible]. [illegible] (77) reports A. [illegible] feeding on [illegible] and [illegible] the insects were [illegible], and [illegible] (77) records A. [illegible] and A. [illegible] [illegible] on [illegible] and [illegible].

[illegible] individuals of all mosquito species collected on July 19 [illegible], development of the eggs had scarcely begun; in one [illegible] of A. [illegible] eggs could be found [illegible], and in one of A. [illegible] about 10 developing eggs could be counted in each ovary. Further dissections on July 25 revealed considerable progress in development, although only [illegible] had [illegible] ready to be laid. A total of 150 eggs could be counted in specimens of A. [illegible], and 100 in A. [illegible] [illegible] specimens of A. [illegible], [illegible] laid eggs in [illegible] before July 23 and 25.

Nectar feeding appears to be a [illegible] of [illegible] mosquitoes, and [illegible], circumstantial evidence [illegible] long [illegible]. The very common woodland orchid [illegible] [illegible] flowers, [illegible] reported by [illegible] (?) to be [illegible] pollinated by mosquitoes, [illegible] of the pollinia adhering to the [illegible] of [illegible], [illegible] orchid flowers, [illegible] [illegible] 23 and 24, [illegible], [illegible] that [illegible] mosquitoes [illegible] carrying the pollinia of this orchid. [illegible] [illegible] [illegible] 12, 13 and 17, [illegible], [illegible] [illegible] [illegible] [illegible], [illegible] [illegible] carrying [illegible] [illegible], [illegible] [illegible] carrying the [illegible], A. [illegible]

reasonable to assume that the probability of a mosquito in feeding on _Habenaria_ picking up the left pollinium is the same as the probability of picking up the right pollinium. If this is so, the probability of a mosquito picking up both pollinia is the square of the probability of it picking up a single pollinium, and the ratio of the number with two pollinia to the number with one is the same as the ratio of the number with one to the number which have visited the orchid. Working on this assumption, it may be stated that no less than 74 per cent of the Churchill mosquitoes attracted to man at the middle of July had fed on _Habenaria obtusata_. This is a remarkably high figure when it is considered that there are numerous other flowers secreting nectar accessible to mosquitoes at this time. Among these may be mentioned _Rhododendron lapponicum_ L., _Ledum palustre_ L. and _Dryas integrifolia_ Vahl., all of which are extremely abundant, and on all of which, in spite of the difficulty of so doing, mosquitoes have been observed resting, and apparently feeding.

Pollinia of _H. obtusata_ have been found on all the species of _Aedes_ except _A. cinereus_, the proboscis of which is less than 2 mm. long. They have not been found however on the small individuals of _A. communis_.

On two occasions mosquitoes have been observed feeding on _Habenaria hyperborea_ L., and figure 7, paid for with no small amount of blood, shows _A. punctor_ preparing to feed on this species. Neither the pollinia of this, nor those of other common species of orchid, however, have been found attached to mosquitoes.

Figure 7: A. punctor preparing to feed on Habenaria hyperborea.

Captive mosquitoes of various species fed readily on sugar solutions of a wide range of concentration in the laboratory. The process of feeding, however, was much slower than feeding on blood, and the quantity consumed at a single feed was never comparable to the size of the normal blood meal.

Observations on mosquitoes feeding on blood are manifold, and need not be prolonged here. Some figures obtained for weights of blood meals are, however, given in Table 1, since these figures are used in flight range calculations in section 3.1.4. The figures for A. stimulans were obtained at Edmonton, using a chemical balance; the remainder at Churchill, using a micro-dynamometer improvised from glass capillary tubing, and calibrated by subdividing sheets of bond paper.

Many of the preceding observations and data were secured during the course of 24 hour collections, in which 2 or 3 observers recorded local weather conditions, collected biting flies and made notes on their activities at hourly intervals throughout a 24 hour period. Further data from these collections are given here, since most of them pertain to mosquitoes.

In 1947 a preliminary 24 hour collection was made in order to investigate the possibilities of this method of working. Equipment and personnel were inadequate, but in spite of this, useful data were obtained. Two sites were selected about seven miles east of Churchill camp and a mile from the shore of Hudson Bay. The first of these (military map reference 024047, figure 23) was in open tundra meadow,

TABLE 1. The body weights and weights of blood meals consumed in milligrams, for various species of mosquitoes.

	A. stimulans	A. communis	A. punctor
Weights of unfed individuals	1.4,1.2,1.5, 1.3,1.4,	1.7,2.0,1.6, 1.8,1.7,	4.4,5.1,4.7, 4.4,3.1,5.7,
Mean unfed weight	1.4	1.8	4.6
Weights of fully fed individuals	3.8,3.0,3.0, 2.2,3.6,	4.8,4.6,4.9, 4.5,4.7,	7.8,8.2,7.1, 6.9,7.3,
Mean fed weight	3.1	4.7	7.5
Mean weight of blood meal	1.7	2.9	2.9
$\frac{\text{Meal weight}}{\text{body weight}}$	1.2	1.6	0.63

Figure 8: A. nearcticus feeding on man; stage one, 1½ minutes.

Figure 9: A. nearcticus feeding on man; stage 2, 2½ minutes.

just to the lee side of a small clump of spruce, and is illustrated in figure 10. The second (025045) was in a wooded area about 200 yards south of this, illustrated in figure 11. Figure 12 shows the nature of the surrounding country.

The first collection was made at 4.00 p.m. on July 24, and the last at 3.00 p.m. on July 25th. Insects were collected at each station with a tube off the person of the observer so long as the light was sufficient, and by sweeping with a net through the cloud of insects on the wing around the observer. Temperature and humidity readings were taken every hour, and periodical observations of cloud conditions, light values, and wind were made.

The observations appeared to indicate that the outstandingly important weather factor in relation to general biting fly activity is wind, with temperature second in importance, but only below a definite limit, which for mosquitoes is certainly appreciably below 50°F. Mosquitoes appear to be indifferent to light intensity. These conclusions are in agreement with the generally accepted idea of relief from biting flies obtained along the sea shore, where the overall wind is fully effective, and where it is supplemented twice daily by local 'land and sea breezes'. Mosquitoes appeared to exhibit some tendency to collect into groups of trees and patches of wooded country after sunset.

In 1948 two 24 hour collections were made, one on the tundra at the site used in 1947 on July 12 - 13, and one in the forest at Warkworth Creek on July 16 - 17. Some of the data from these are presented in graphical form in figures

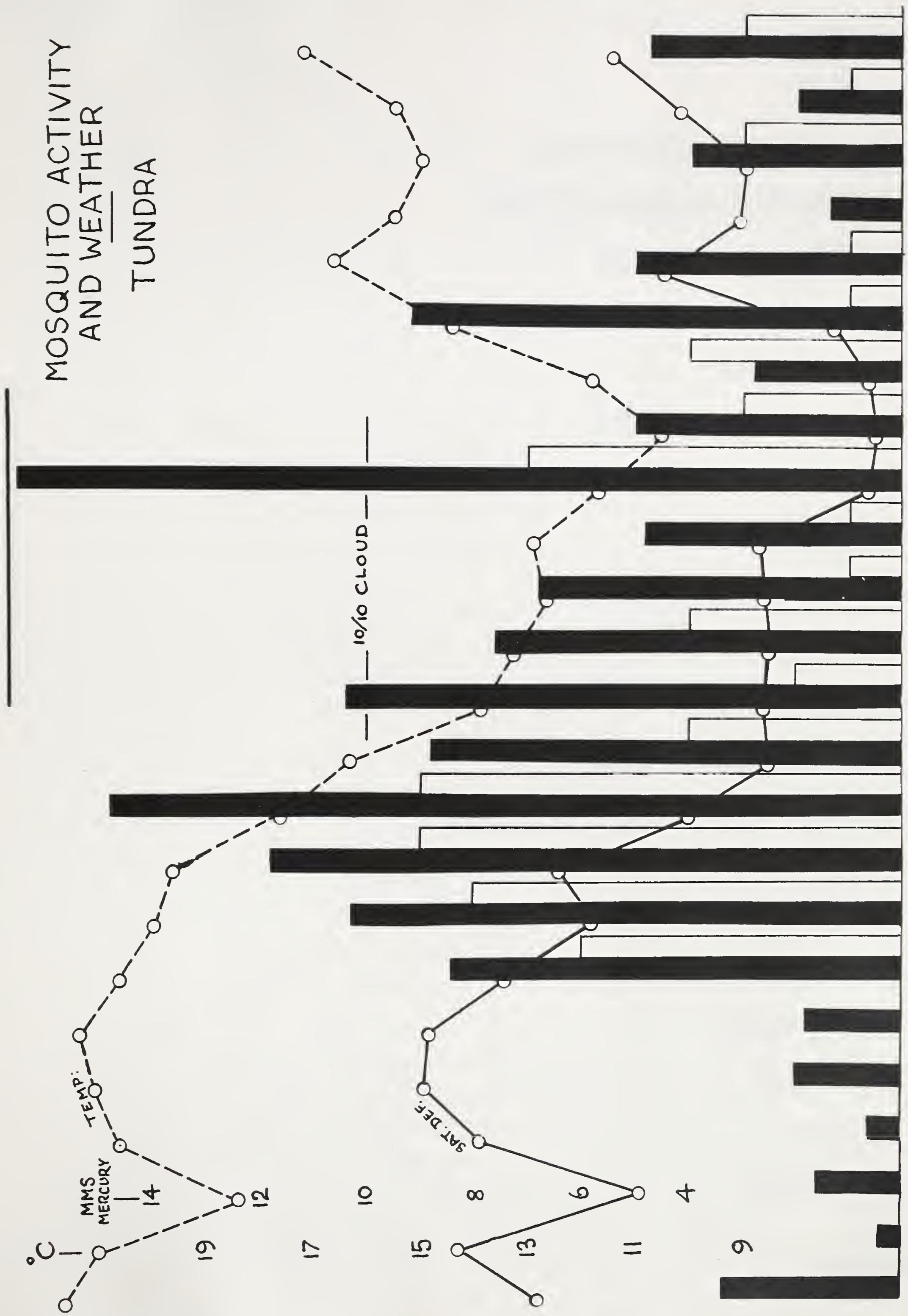
Figure 10: The tundra collecting site.

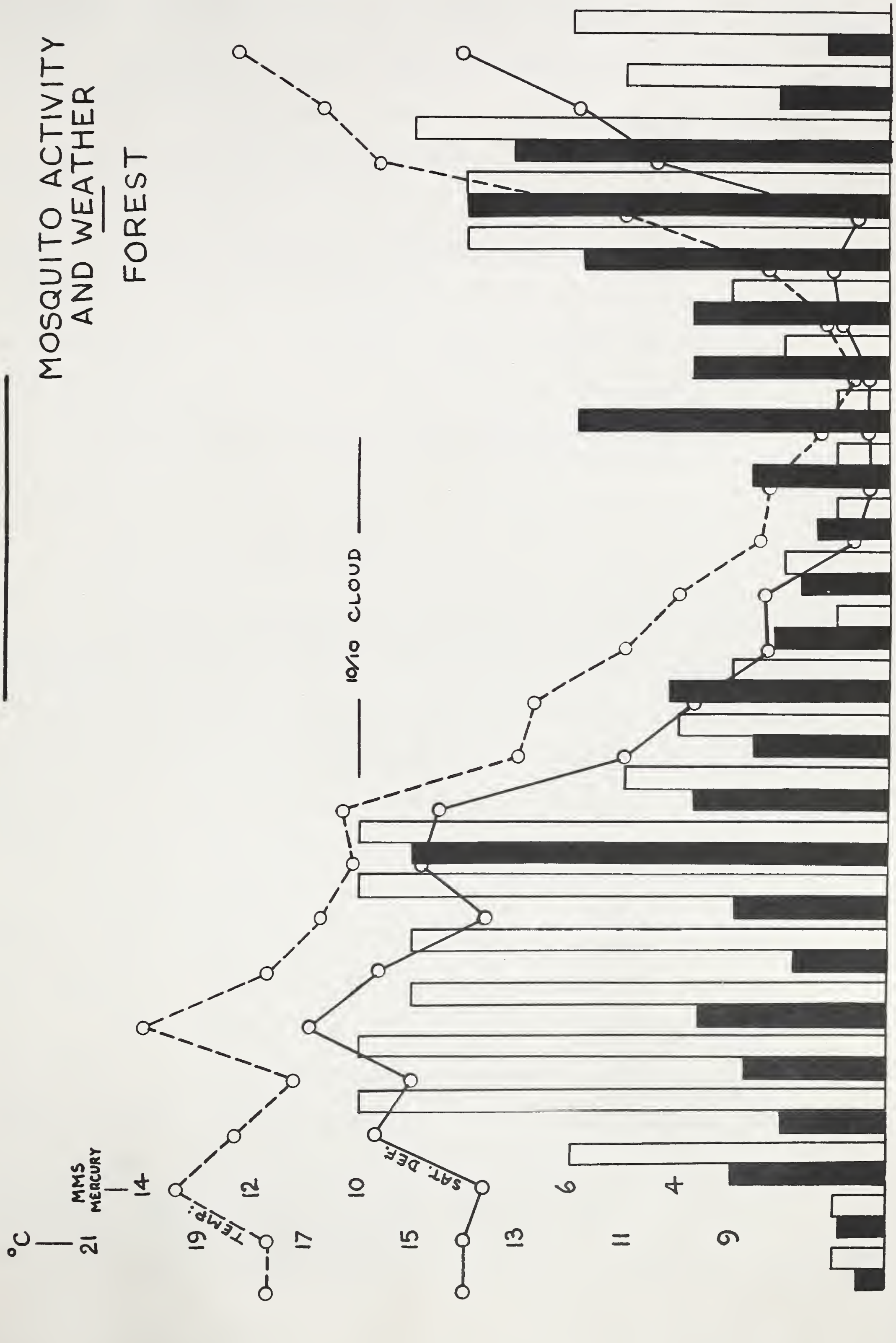
Figure 11. The wooded collecting site.

Figure 12: A general view of the 24 hour collecting area.

13 and 14. In these graphs the black columns represent a measure of the mosquito interest in man, and are computed arbitrarily from the biting rate and alighting rate figures. Biting rate figures represent the number of mosquitoes engaged in feeding during the second minute in which a forearm is exposed on the lee side of the body. Alighting rate is a count of the number of mosquitoes alighting on the front of the trousers between side seams from waist to knee, in the second minute of standing still, facing downwind. Open columns represent the proportion of the sky covered by cloud, and the broken and solid lines represent temperature and saturation deficiency respectively. The heavy line at the top of each graph represents the hours of darkness; records commenced between 10 and 11 a.m.

The tundra graph shows remarkably good correlation between cloudiness and mosquito interest in man, a fact which has been previously observed by Hunter (71). There is a rough peak of activity shortly after nightfall, when both temperature and saturation deficiency were falling rapidly. In the forest graph, as would be expected, the correlation with cloudiness is less well marked, and there are two quite well defined peaks of mosquito interest, one shortly before sundown, and a second shortly after sunrise. Again, no inverse correlation with saturation deficiency is shown, biting rates often remaining surprisingly high at high saturation deficiencies. It is interesting to note that quite high biting rates were recorded at temperatures below 7°C; Mellanby (40) records the flight threshold of <u>A. punctor</u>, a dominant species in this collection,


MOSQUITO ACTIVITY
AND WEATHER
TUNDRA
10/10 CLOUD
TEMP.
SAT. DEF.
°C
MMS MERCURY
19
17
15
13
11
9
14
12
10
8
6
4


MOSQUITO ACTIVITY
AND WEATHER
FOREST
10/10 CLOUD
°C
21
19
17
15
13
11
9
MMS MERCURY
14
12
10
6
4
TEMP.
SAT. DEF.

as about 10°C in Lapland. Wind speed throughout both of these 24 hour periods was low, so that no confirmation of 1947 observations was obtained, except as regards the absence of any direct effect of light intensity. These data do not support the statement of Matheson (37) that all our far northern Aedes species are primarily diurnal. Further data are required before much specific variation in activity will show up, but an examination of the material taken at these collections reveals that A. cinereus is restricted in its biting activity to a few hours before sunset, and again after sunrise.

3.1.4. Flight Range:

The difficulties of measuring the flight range of an insect by the normal method of releasing marked individuals and recording the distance to the point of recapture, increase in proportion to the square of the flight range, and are immeasurably further increased over terrain such as that at Churchill, where the observer's own power of movement is very restricted. It is generally accepted that the more northern mosquito species have a very considerable range of flight, so that a new approach to this problem had to be found.

The flight range of mosquitoes determines the area over which it is necessary to kill larvae to ensure protection from adults for a given locality. This is its primary practical application. Population pressure is a major stimulus to movement; this cancels out under normal conditions, but is at its maximum in infiltration into an area cleared by insecticide

as about 10°C in Lapland. Since annual temperature data of these of hour periods was lost, no kind of verification of these observations was obtained, except a remark the absence of any direct effect of light intensity. These data do not support the statement of [illegible] (19[illegible]) that all but the [illegible] *Aedes* species are entirely diurnal. Periods both are required before such sensible [illegible] can be accurately [illegible], an examination of the material taken from these collections reveals that *A. cinereus* is restricted in its biting activity to a few hours before sunset, and night after sunrise.

2.1.4. Flight Range.

The difficulties of measuring the flight range of an insect by the normal method of releasing marked individuals and recording the distance to the point of recapture, increase in proportion to the square of the flight range, and are considerably further increased over terrain such as that at Churchill, where the observer's own power of movement is very restricted. It is generally accepted that the more northern mosquito species have a very considerable range of flight, so that a new approach to this problem had to be found.

The flight range of mosquitoes determines the area over which it is necessary to kill larvae to ensure protection from adults for a given locality. This is its primary economic application. Temperature increase is a major stimulus to movement; this extends out under normal conditions. Much of its maximum is infiltration into an area changes in [illegible]

spraying. It follows that the maximum possible flight range has greater practical significance than flight range under normal conditions.

The normal method of determining flight range measures actual distances flown, and concludes that the maximum flight range is not less than the greatest of these distances. The method used here has the advantage of approaching the answer from the opposite direction; the maximum flight range which is theoretically possible being determined, it may then be stated that the flight range is not greater than this figure. Unfortunately it can only be applied to uninterrupted flights. Flight range data based on distances from known breeding grounds at which adults are captured are always open to suspicion in that there may be unknown breeding grounds, or that adults may have been carried by their hosts or by man's vehicles.

The method used is to determine experimentally the stomach capacity of the insect, the composition of its normal food and hence the energy obtainable from this by respiratory processes, the mass of the insect and hence the energy required to keep it airborne for a given time, and finally the wind resistance at various speeds and hence the energy required to travel unit distance. From these data a simple equation can be obtained for any air speed, solution of which will give the range at such a speed. The solution of a series of such equations enables range to be plotted against air speed, the resulting curve showing a single maximum range. No account has been taken of the energy stored in the fat body, and

elsewhere in the newly emerged adult. This is small in mosquitoes and is probably largely exhausted in mating and preliminary feeding activities. It has necessarily been assumed that the wind resistance of the stationary wings is the same as that of the wings in motion.

Only a preliminary exploratory application of this method, using A. punctor has been made so far, but the results are sufficiently promising to justify further work, and are reproduced here:

A. Stomach capacity: It is true that mosquitoes do not normally engorge on nectar, the food presumably used for migratory flights, to the extent that they do on blood. On the other hand there is no evidence that migratory species before setting out on a long flight do not do so, and, since a maximum figure is required, stomach capacity has been taken as the space occupied by a blood meal of mean weight. Taking the specific gravity of human blood to be 1.06 (53), the figures in Table 1. show this to be 0.00274 ccs.

B. Food composition and energy per meal: Samples of nectar from Rhododendron lapponicum which is believed to be utilised by mosquitoes were collected at Churchill at 3.0 p.m. on July 1 by means of glass capillary tubes, and sealed into these. The amount obtained from a single flower was very variable, ranging from 0.00011 ccs. to 0.00088 ccs., but the 0.00274 ccs. required by A. punctor would be readily available from a single plant. Subsequent analysis showed this nectar to have the following composition: reducing sugars, 48 per cent; non-reducing

sugars, 41%; other matter not estimated, including water, 11 per cent.

Assuming the reducing sugars to be mainly glucose, with a heat of combustion of 673 kgm. cals. per gm. molecular weight, and the non-reducing sugars mainly sucrose, for which the figure is 1349.6 kgm. cals., the energy available in 0.00274 ccs. of this material would be 12.7 calories or 5.30×10^8 ergs. Unfortunately little is known of the efficiency with which the insect can transform this chemical energy into mechanical energy, but it may be assumed that this is not much less than that of a mammal such as man (63), for which an average maximum is 25 per cent (54). This would give 1.325×10^8 ergs available for flight. Still less is known of the efficiency with which insect wings can translate this muscular energy into forward aerial motion, but since the main loss here is in the form of kinetic energy of the slipstream, this is probably not more than 10 per cent, leaving 1.193×10^8 ergs of useful energy available.

C. <u>Insect mass and energy required to remain airborne</u>: Since the rate of loss of mass depends on the rate of consumption of energy, which in turn depends on the mass at any particular instant, the solution of a differential equation should be used here, but in a necessarily approximate preliminary investigation, sufficient accuracy is obtained by assuming that the mass remains constant at its mean value, which from the figures in Table 1. is 0.00605 gms. The energy required to remain airborne is equal to the rate at which gravity would

[illegible]
11 per cent.

[illegible]

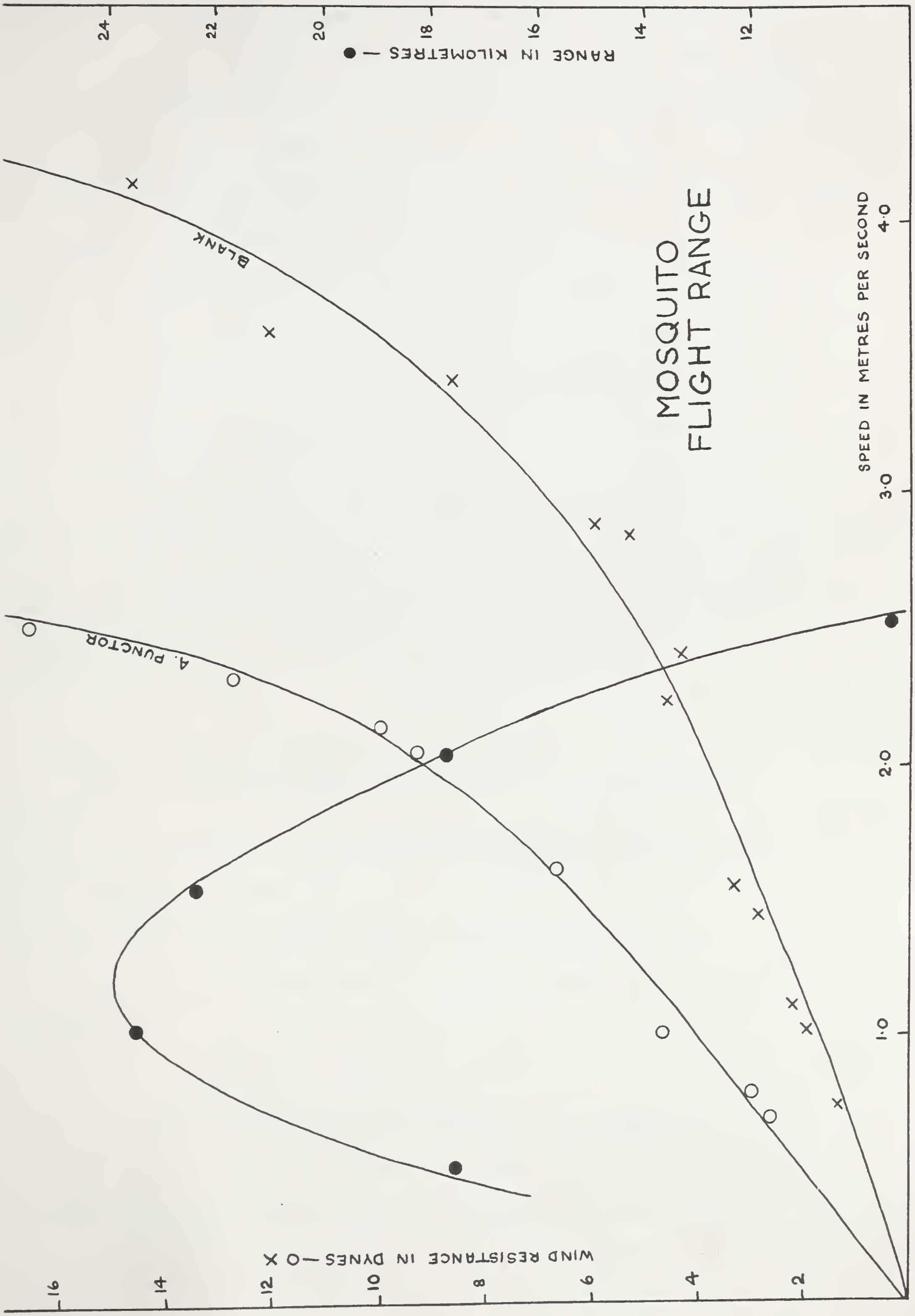
[illegible] per cent [illegible]

[illegible]

do work on the insect; this is $\frac{0.00605 \times 981^2}{2}$ or 2910 ergs per second. That is, A. punctor on a meal of this nature could remain airborne, without forward motion for $\frac{1.193 \times 10^8}{2910 \times 60}$ minutes, or 11 hours 20 minutes.

D. Wind resistance at various speeds: This was measured with the aid of the micro-dynamometer referred to insection 3.1.3. The instrument was set up with the glass capillary vertical, with the free end below dipping into a cell built on to the side of the scale and containing a glycerol-water mixture of suitable viscosity to damp out vibrations. Adjacent to it was a portable anemometer, and at a variable distance from the two instruments, a 110 volt 1 ampere table fan with 16" diameter rotor, and a three stage resistance speed control. The apparatus was first calibrated by taking a series of corresponding readings of wind speed on the anemometer and deflection of the dynamometer, and plotting these against each other. A specimen of A. punctor half fed on blood, recently killed and set in flying attitude, was then mounted with the load position of the glass capillary at the side of the mesothorax, and the readings were repeated. The curves obtained after converting the dynamometer deflections to dynes and the anemometer readings to metres per second, are given in figure 15, and enable the wind resistance at any desired speed to be read off.

At an air speed of 0.5 metres per second (1.12 m.p.h.) the wind resistance is 1.0 dynes. Supposing the range to be R metres, the time in flight will be 2R seconds. The work


MOSQUITO
FLIGHT RANGE
BLANK
A. PUNCTOR
RANGE IN KILOMETRES — ●
12 14 16 18 20 22 24
WIND RESISTANCE IN DYNES — O X
2 4 6 8 10 12 14 16
SPEED IN METRES PER SECOND
1·0 2·0 3·0 4·0

done in remaining airborne will be 2910 x 2R ergs, and the energy used in forward motion will be 1.0 x R x 1000 ergs. The sum of these two must equal the total energy available, i.e. 1.193×10^8 ergs, and the solution of this equation gives R the value $\frac{1.193 \times 10^8}{6820}$ metres. This is 17,500 metres or about 11 miles. Similarly the following figures may be obtained:

At 1.0 metres per second: 23,400 metres.

At 1.5 metres per second: 22,300 metres.

At 2.0 metres per second: 17,700 metres.

At 2.5 metres per second: 9,400 metres.
(5.6 m.p.h.)

By plotting these figures on a graph (Fig. 15) it is seen that the maximum possible uninterrupted flight range in still air for A. punctor is not greater than 24 kilometres. A. punctor is not regarded as a migratory species.

3.2. On the Biology and Behaviour of Blackflies.

Studies on the immature stages of blackflies have been impeded by the difficulty of laboratory rearing, except for pupa to adult, and by the impossibility at present of identifying any stages earlier than the late last larval instar.

Observations have been made on the hatching of eggs, which from the subsequent abundance of S. venustum in the stream from which they were collected, presumably belonged to this species. Like many insect eggs, these darken as they mature; this is brought about partly by pigmentation in the

chorion and embryonic integument, and partly by the development of a prominent blue-black hatching spine on the vertex, and two dark eyespots on either side of the head. The front of the embryonic head fits closely into the apex or smallest angle of the egg, which in dorsal view has an unusual rounded triangular shape. The thorax and abdomen are coiled into an S-shape and fill the remainder of the egg. Contractile waves in the abdomen, movements of the mouthparts, and partial rotations of the head, which apparently scratch the chorion with the hatching spine can all be observed prior to eclosion. The chorion eventually ruptures in such a manner as to allow the small angle of the triangle to hinge open, and the active young larva to emerge head first; the whole process, from the first appearance of the split, occupying about 20 minutes in the laboratory.

These eggs are nearly always found in a very characteristic situation. Where sedges are bent by the current so that the top portion of the leaf lies parallel to and just below the surface of the stream, the eggs of this species will be found cemented to the upper side of the leaf within an inch or so of its tip. The mechanics of oviposition in such a situation are readily comprehensible. The egg just prior to hatching, and a typical oviposition site are shown in figures 16 and 17 respectively.

Fish feed readily on blackfly larvae. As many as 71 larvae of all ages have been taken from the stomach of a sucker (Catostomus sp.) from a sparsely infested creek, and 73 very young larvae from the stomach of a stickleback (Pungitius

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

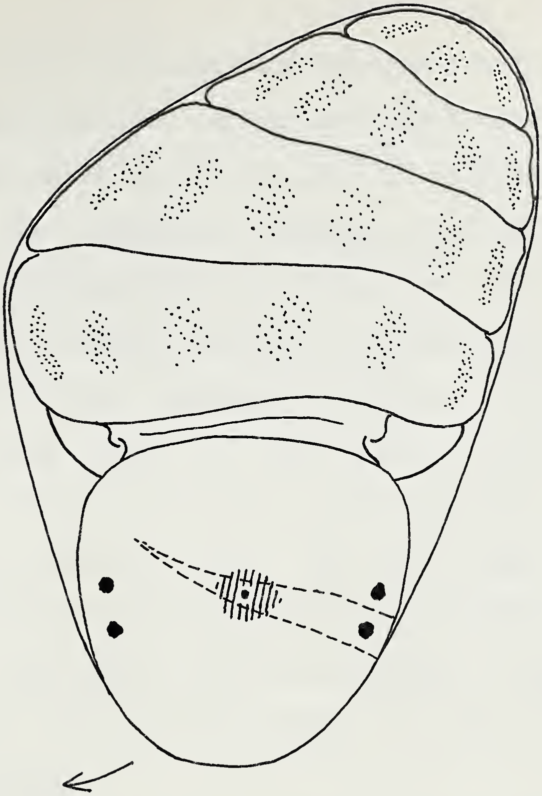
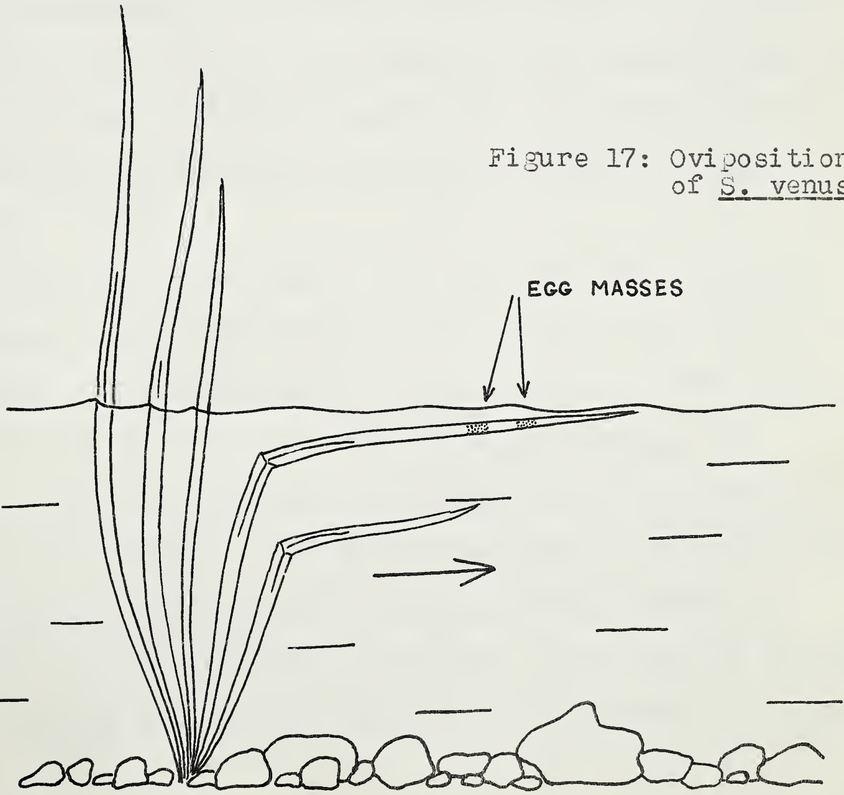


Figure 16: A mature egg of S. venustum

Figure 17: Oviposition site of S. venustum



pungitius) from a stream which observers had reported to be free from infestation. Larvae have also been found in the stomach of the northern wood frog, and of jackfish; in the latter animal they were apparently ingested incidentally along with a mat of filamentous algae to which they had been attached.

Very little is known of the mating and feeding habits of adult blackflies. Eusimulium species A resembles E. lascivum in that it mates freely on vegetation at the sides of the stream from which it emerged, on the clothing and person, and even in the collectors vials. The only other Churchill species of which the mating habits have been observed is E. aureum, of which a pair was taken off the clothing, in copula, at 11.0 a.m. on July 17 in the woods adjoining the creek in which the species develops.

S. venustum is the only species which is a serious pest of man at Churchill; this species takes rather longer to feed than do mosquitoes, but in spite of its smaller size it takes almost as large a meal, weights of 2.4 and 1.7 mgms. having been recorded.

There are some indications that with the exception of S. arcticum, the blackflies do not travel far in search of a blood meal. Of 265 blackflies taken during the 1947 24 hour collection, only 2 or 0.7 per cent were S. vittatum, the breeding of which is believed to be confined to the Churchill River, nine miles west of the collection site. Critical light values for blackfly flight and feeding recorded during the 1948 24 hour collections were as follows: cessation of biting, tundra 900 lumens per sq. ft., forest 500; cessation of flying,

tundra 900, forest 500; resumption of flying, tundra 1800, forest 1250; resumption of biting, tundra 1800, forest 1750 lumens per sq. ft.

3.3. Biology and Behaviour of Tabanids.

The abundance of certain tabanid species leads to speculation as to the larval food material. Hine (29) successfully reared a number of species of _Hybomitra_ on small crustacea and on earthworms, both living and dead. Stone (56) was able to repeat this but found mosquito larvae to be the best food for the young tabanid larvae. It would seem possible, therefore, that the enormous numbers of mosquito larvae stranded from drying pools may form a material element in the diet of one or more species of _Hybomitra_.

Larvae in the insectary in 1948, species as yet unknown, fed avidly on small gastropods, and the presence of empty shells of this snail in the field provided a guide to the whereabouts of larvae. The cannibalistic habits of these larvae probably explain their very scattered distribution, which makes them very much harder to collect than the abundance of adults would lead one to suppose. The chemical treatment recommended by Bailey (7), but with Triton X-100 replacing sodium lauryl sulphate, and a trade preparation sold to anglers for bringing worms to the surface, were used extensively in 1948 without revealing anything but extremely sparse larval populations. Cameron (13) states that _Chrysops_ larvae will not feed on living animal material, but Waterston (84) reports

them as preying on mosquito larvae, under laboratory conditions.

The few instances of mating observed took place at various times of day. *H. gracilipalpis* seemingly mates as a rule about the middle of the morning. Females at least, apparently feed on flowers soon after emerging; most of the earlier specimens taken of nearly all species, were liberally dusted with pollen. Specimens of *Chrysops mitis* were collected off flowers. Specimens of *H. affinis* fed readily on various concentrations of sugar solution in the laboratory, but would not take expressed human blood; the piercing procedure is presumably necessary to condition the insect for blood feeding.

The effect of a meal of human blood on egg development in *H. affinis* is astounding. Specimens collected in the field on July 20 had very rudimentary ovaries, the abdomen being very largely filled with air sacs, and no eggs discernible. One of these given a full blood meal, and killed three days later was found to have the abdomen swollen, and filled almost to bursting with well developed eggs. The number of these was estimated at 600.

With the exception of *H. affinis* and *H. septentrionalis* the adults of no species of either genus were found in numbers more than a few hundred yards from woodland; this was especially true of the *Chrysops* species which were seldom taken outside of the woods.

The adults of several species of *Hybomitra*, *H. affinis* conspicuous amongst them, are attracted in large numbers to

vehicles, including trucks, trains, and aircraft. Large numbers of flies would collect around a vehicle (Fig.18) while an observer standing a few yards away might pass practically unmolested. Stone (56) suggests that they are attracted by the movement, but adds that they will collect around a standing automobile. This fact was also observed, but in every instance it was around a standing vehicle which had been in motion, and was warm in consequence. Warmth appears to be an attractive factor, while movement stimulates pursuit. Certainly it is of no use attempting to run, or even to drive, away from tabanids over the terrain around Churchill. Specimens which appeared to be H. affinis were observed to lose ground only slowly when in pursuit of a train travelling at approximately 30 m.p.h. On the morning of July 12, 1947, and a few days subsequent to this, several observers reported a caribou calf, apparently separated from the herd, careering madly around the Churchill locality, pursued by a small cloud of tabanids. The animal appeared in very poor condition, presumably as a result of the attentions of the flies. Chained dogs, however, were not seen to be attacked by large numbers of tabanids, possibly on account of their inability to run away.

Activity, and especially biting activity, of tabanids is far more influenced by weather conditions than is that of mosquitoes. In cool, damp, overcast and windy weather few, if any tabanids are seen on the wing. The weather factors of greatest importance seem to be temperature and sunlight; high relative humidity appears to be associated with absence of biting only secondarily, by virtue of its association with low temperature.

Figure 18: Tabanids in flight around a stationary vehicle.

Biting was rare at temperatures below $55^{\circ}F$, and even above this temperature would not normally occur unless there had previously been an appreciable period of sunshine on the same day. The well established preference of tabanids for biting through wet skin (57) was confirmed by the observations of personnel working in blackfly streams, and by bathers. When up to the neck in water, H. septentrionalis especially, will circle the head continuously at a distance of about a metre, coming in to bite as soon as the rest of the body is exposed.

During the 1947 24 hour collection, tabanids were no longer on the wing about half an hour after sunset. The temperature at that time fell below $65^{\circ}F$. and the light value below 500 lumens per sq.ft. Activity was not resumed until two hours after sunrise, when the temperature was $55^{\circ}F$. and the light value 2000 lumens p.sq.ft. H. affinis was the most persistent species in each instance, but possibly only apparently so, on account of its greater abundance. These observations were confirmed during the 24 hour collections in 1948.

4. THE INFLUENCE OF BITING FLIES ON MAN AND ON HIS ACTIVITIES

There are many reports, some authentic, some otherwise, of individual men and animals being killed by biting flies, either directly by loss of blood, or indirectly through the reaction to toxic materials injected. There is no doubt whatever but that current methods of protection - protective, or even normal 'sensible' clothing, and a modern repellent - can entirely eliminate such occurrences without undue expenditure of time, effort, or materials. There remain, however, very considerable discomforts and delays, risks of secondary infections, and in susceptible or sensitized persons reactions to toxic materials which not infrequently require hospital treatment. In a really intense blackfly and mosquito population, even conversation becomes difficult unless one is prepared to swallow many of the insects. Finally, there is another effect of biting fly attack which has not been fully considered in the past, a psycho-physiological effect. This was clearly demonstrated on several occasions at Churchill, in particular during the camp at Warkworth Creek in 1947, and during the 24 hour collecting camps.

4.1. Physiological Influences.

As opportunity offered, observations were made on the reactions to bites of both mosquitoes and blackflies, with the

object of confirming for the species encountered here, the accepted opinions that: repeated bites result in a degree of immunity, and that the reaction is less if the insect is allowed to feed to completion (47). Observations were not sufficiently numerous for definite conclusions to be drawn, but what evidence there is tends to support these views, and this evidence is recorded here:

Mosquitoes: Culiseta alaskaensis Ludl. June 18, just above elbow, fed to completion in $2\frac{1}{2}$ minutes. Feeding was preceded by a preliminary probe $\frac{1}{2}$" from final puncture. Irritation was possibly slightly greater at the trial puncture. Symptoms just detectable after 30 hours.

Aedes excrucians. July 17, partial feeding inside right knee. Considerable irritation directly after biting. After 9 hours a small reddish weal, very slight irritation. 24 hours, no symptoms detectable.

A. nigripes. July 17, complete feeding 2" above right knee. Some irritation during feeding and for a few minutes afterwards. After 8 hours slight hardness, small reddish weal and very slight irritation. 24 hours very slight irritation, faint reddish mark.

A. nigripes. July 17, complete feeding 1" below elbow. Slight irritation during feeding. After 6 hours no detectable symptoms.

A. nigripes. July 17, partial feeding upper left forearm. Slight irritation during feeding; after 4 hours slight reddish weal and slight irritation. After 18 hours no symptoms detectable.

Blackflies: Four bites of S. venustum were observed on July 17. At the first two of these, the insect was allowed to feed to sateity, at the other two the insect was removed shortly after starting feeding.

1. Below and inside right knee. Feeding time 5 minutes. After 4 hours slight swelling and moderate irritation. After 14 hours no swelling, slight irritation. After 3 days slight irritation but no other symptoms. After 5 days, no symptoms.

2. Outside left leg, 4" above ankle. Very slight irritation immediately after bite. Swelling appeared after 4 hours, $1\frac{1}{2}$" across, irritation considerable.

After 14 hours no swelling, but still some irritation. Slight irritation after 3 days, none after 5 days.

3. Outside left leg, 12" above ankle. Irritation considerable and continuous from time of bite onwards; a hard lump around puncture. After 5 hours swelling about 3" across and irritation severe. After 14 hours swelling slight and moderate irritation. After 3 days, no swelling but moderate irritation. Appreciable irritation remained after 5 days.

4. Outside right leg, 4" below knee. Symptoms as for No. 3 but somewhat more severe.

There was no sensation of pain during piercing; in each instance the insect crawled down through the hairs and held itself practically perpendicular to the skin surface. There was a slight flow of blood from all four bites for a few minutes after feeding ceased.

Concerning the direct effect of loss of blood, a simple calculation on this is of interest. The highest mosquito biting rate recorded at Churchill during 1947-8 was 160 bites per minute. The total skin surface is about 33 times that of the forearm, so that a completely unprotected man (materials often used for summer clothing give very little protection against northern species) could receive a maximum of 5290 bites per minute. At 2.5 mgms. per bite (see Table 1.), the blood lost per minute would be 13.2 gms. The symptoms resulting from a loss of 50 per cent of the blood are certainly severe enough (64) to prevent the victim from progressing any distance across the Churchill terrain. Assuming that the blood composes 7.7 per cent of the body weight, and has a specific gravity of 1.06 (54), this situation could be reached in about three hours on account of mosquitoes alone. Although the biting rates for blackflies and tabanids are both much lower, the loss of blood from their larger punctures, in which an anticoagulin is present, would contribute materially to exhaustion from this cause.

In so far as the irritation caused by mosquito bites is concerned, Macloskie (35) regarded the middle lobe of the salivary gland as the source of the poison concerned, Riley and Johannsen (47) refer to the work of Schaudinn (49) and of Roy (48). Results appear to be based on Anopheline species only, and to demonstrate somewhat inconclusively that irritation is due to an enzyme produced by constant commensal fungi (yeasts ?) living in the oesophageal diverticula. The results of Cornwall and Patton (16) seem to support this view, and Imms (31) quotes Hindle, also in support of it. Bruck (12) however, extracted a toxin which he named culicin from the bodies of mosquitoes and assumed this came from the salivary glands, and McKinley (39) has demonstrated convincingly the presence of a poison in the salivary glands of *Aedes aegypti*. None of this work relates to northern species of *Aedes*; I have not had access to the work of Hecht (28) who is reported to have summarised the information available in 1928.

With regard to the situation in blackflies, Patton and Evans (41) figure the alimentary system of *S. ornatum* with a single oesophageal diverticulum, and suggest a toxic enzyme in the saliva of some species as the irritant. Both in 1947 and in 1948 the reaction to blackfly bites diminished markedly as the season progressed; this has been regarded as the development of a temporary immunity as a result of bites received. In view of the very different environmental conditions under which the later generations of blackflies develop, however, this could equally well be attributed to a physiological difference in these generations of blackflies. This appears to be all that is known

on the subject, although, at least to the susceptible newcomer, the toxic effect of the blackfly bite is undoubtedly the most potent weapon in the whole biting fly armoury. It is believed to be this toxic material which is the cause of numerous deaths of cattle in Saskatchewan when attacked by S. arcticum (46).

Typical reactions to the bites of mosquitoes and of blackflies are shown in figures 19 and 20 respectively.

Observations on the bites of tabanids are few; these insects are so clumsy over piercing the skin that they rarely get away with a complete meal from man. As a group, they do not appear to have 'learnt' yet that man has hands, and it is usually a biological error for a tabanid to attempt to secure a meal from man. Considerable personal variation in liability to attack has been noticed. The species of Chrysops appear to bite man more freely than do Hybomitra, but none is a serious biter of man when he is protected by suitable clothing and a good repellent.

Tabanids gain access to buildings in considerable numbers, but cause annoyance there more by their efforts to get out again than by any attempts to bite. In fact , no instance of a tabanid biting indoors has been recorded at Churchill.

4.2. Psychological Influences.

The psychological effects of biting fly attack seem to result partly from the immediate stinging sensation of the insect mouthparts, partly from the manual 'removal reaction' to this, and partly from the continual impact of insects on the face and person. Given equal numbers, tabanids are regarded

Figure 19: A typical reaction to the puncture of a mosquito in a susceptible individual.

Figure 20: A typical reaction to blackfly punctures.

as the most important group in relation to each of these three factors, followed by mosquitoes and finally blackflies. The two genera of tabanids however, are very different in their effects. The *Chrysops* species contribute to the psychological menace mainly by virtue of their rather silent approach and furtive alighting, *Hybomitra* species on account of their swift and noisy flight, and the momentum of their impacts on the person.

The typical 'removal reaction' is illustrated in figures 21 and 22. It might be supposed that this, along with the first factor, could be eliminated by protective clothing and repellents, but such is not the case; the reaction may be evoked by insects alighting, but not biting, or even in certain circumstances by non-existent insects.

The combined influence of these three factors presents a more serious problem in our present state of knowledge than the problem of direct physiological effects. This combined influence would, it is believed, also prove far more serious in military operations, causing as it does, a serious reduction in individual efficiency, and an even more serious lowering of group morale. Carried to the extreme, it is considered that the susceptible individual would become a liability rather than an asset from these causes sooner than from direct physiological effects; the rapidity with which such a person can become worked up into an emotional state bordering on dementia as a result of the continually accelerated and increasingly ineffective removal reactions, has to be seen to be believed.

Figure 21: The removal reaction (1).
(white whale in foreground).

Figure 22: The removal reaction (2).

More knowledge of this problem is required before definite solutions can be proposed; it is possible, for instance, that the effects may be very different in a large body of men. Tentaive proposals for combating these factors are given in section 5, and improvements in these methods of personal protection will certainly play their part.

4.3. Indirect Influences of Biting Flies.

None of the Churchill species of biting flies is known to serve as a true vector for any disease or parasite of man in the Churchill area. The possibility of mechanical transmission of disease by biting flies is also remote at present, in view of the very sparse human population, and the resulting extreme improbability of any individual insect taking blood meals from two humans.

S. venustum however transmits an important disease of wild and domestic ducks, caused by a protozoon parasite Leucocytozoon anatis Wickware, which is closely related to the malaria plasmodia (75). The cycle of events in this disease is comparable with that in malaria, and it may cause heavy mortality; it has recently been shown, however, that it will not respond to treatment with anti-malarial drugs (21).

Scott (82) has shown that H. septentrionalis is capable of transmitting swamp fever or infectious anaemia of horses, and various workers (79,85) have demonstrated the ability of the filarial parasite of dogs Dirofilaria immitis Leidy to develop in A. cinereus, A. punctor, and possibly A. flavescens and A. excrucians. Tularaemia and Plasmodium gallinaceum have

also been transmitted experimentally by _H. septentrionalis_ (76) and _A. cinereus_ (74), and by _A. campestris_ (65) respectively.

Although horses have been maintained at the extreme point of the Churchill peninsula , where the full benefit of sea breezes is obtained, in general the larger domestic animals are excluded from the area on account of biting flies. Most caribou move out northwards along the shore line, before the flies emerge; the Churchill butcher reports that animals from the forest can be distinguished at once by the presence of bites all over the body, the bites on those from the tundra being concentrated near the feet, presumably on account of wind. Husky dogs endure a miserable existence in fly time, and attempt to emulate the lemming, burrowing into the ground to secure a measure of protection.

Further south, mosquitoes are blamed for reduction in land values, for crop losses through impeding harvesting operations at the best time, for general loss of working time on outdoor employment, and for impairment of health through preventing outdoor recreational activities. Only the last two of these factors are applicable in northern regions.

5. EXPERIMENTS ON THE CONTROL OF BITING FLIES

Three approaches to the problem of biting fly control are possible. The first and most obvious method is the application of chemical insecticides, mainly against the larval stages. This is the simplest method, cheapest at the start perhaps, since less fundamental work is required, but probably most expensive in the long run, since once started it may bring about conditions which demand its continuation. It involves a risk of unforeseen consequences. The second is to so alter their habitat that they will never develop in troublesome numbers; this may not be practicable, and complete control by this method would certainly require vastly more knowledge than we have at present. The third, the safest and perhaps the most civilized method, is to let them live, but to arrange matters so that they are kept at a comfortable distance from man, and from animals on which he is dependent. What particular combination of these methods is employed will be decided by circumstances.

5.1. Chemical means for the Reduction of Numbers.

Chemical methods for the control of malaria carrying species are well established. The principle objects of this work were firstly, to discover what modifications would be

required in these methods for the control of northern species of Aedes; secondly, to adapt the technique of preflooding treatments developed against salt marsh mosquitoes at Orlando, Florida, for use in the north; and finally to explore the possibilities of the chemical control of blackflies.

Results of experiments involving the application of a variety of recently discovered insecticides against mosquito larvae from ground equipment, give no suggestion that any of these can compete with DDT, although some of them are no less toxic.

The preflooding application of DDT on the frozen ground, or on ice and snow cover offers the following advantages over normal methods of treatment: movement over the ground is much easier at this time; DDT has a lower LD 50 for newly hatched mosquito larvae, and DDT has a negative temperature coefficient of toxicity. In practice however, much material may be lost from snow drifting and heavy run-off at thawing, and the enormous areas which require to be treated dictate application from the air, so that these advantages are largely discounted.

Results of several experiments on the aerial application of DDT in oil solutions indicate that the dosage required for the control of Aedes larvae is about 0.5 lbs DDT per acre, or nearly five times that required for Anopheles control, and also that very large areas would have to be treated to secure freedom from mosquitoes for the season at the centre of the area. This agrees with data on the flight range of these species.

Several tests of ground applications of DDT in aerosol form against mosquito larvae and adults, and tests of a number of materials against blackfly larvae were made. Detailed accounts of these experiments follow.

5.1.1. Experiments with the Hochberg-Lamer Aerosol Generator against Mosquito Larvae:

Two experiments were carried out in the second half of June 1947 to investigate the effectiveness of DDT aerosols against mosquito larvae in the open under the conditions found at Churchill. Material was dispensed from 500 yard base lines, and entomological observations were carried out to a depth of about 600 yards from these. The plot for the earlier experiment was on tundra meadow, and for the later, on terrain with a heavy covering of birch and willow shrubs, adjoining a tidal flat. These areas are marked (1) and (2) on figure 23. The material was dispensed with an early model of the Hochberg-Lamer aerosol generator (inventor's model no.4) (32) which was mounted on a tracked amphibious trailer containing the tanks of insecticide and the fuel for the generator, and towed behind a snowmobile (Fig.25).

DDT was supplied to the generator in the form of an emulsion of the following composition:

Lubricating oil (equivalent SAE 10)	5 imperial gallons
Xylene	$1\frac{1}{4}$ imp.gals.
DDT	$4\frac{1}{2}$ lbs.
Triton X-100 emulsifier	$2\frac{1}{4}$ lbs.
Water	5 imp.gals.

and this mixture was dispensed at the rate of about 1/3 of a

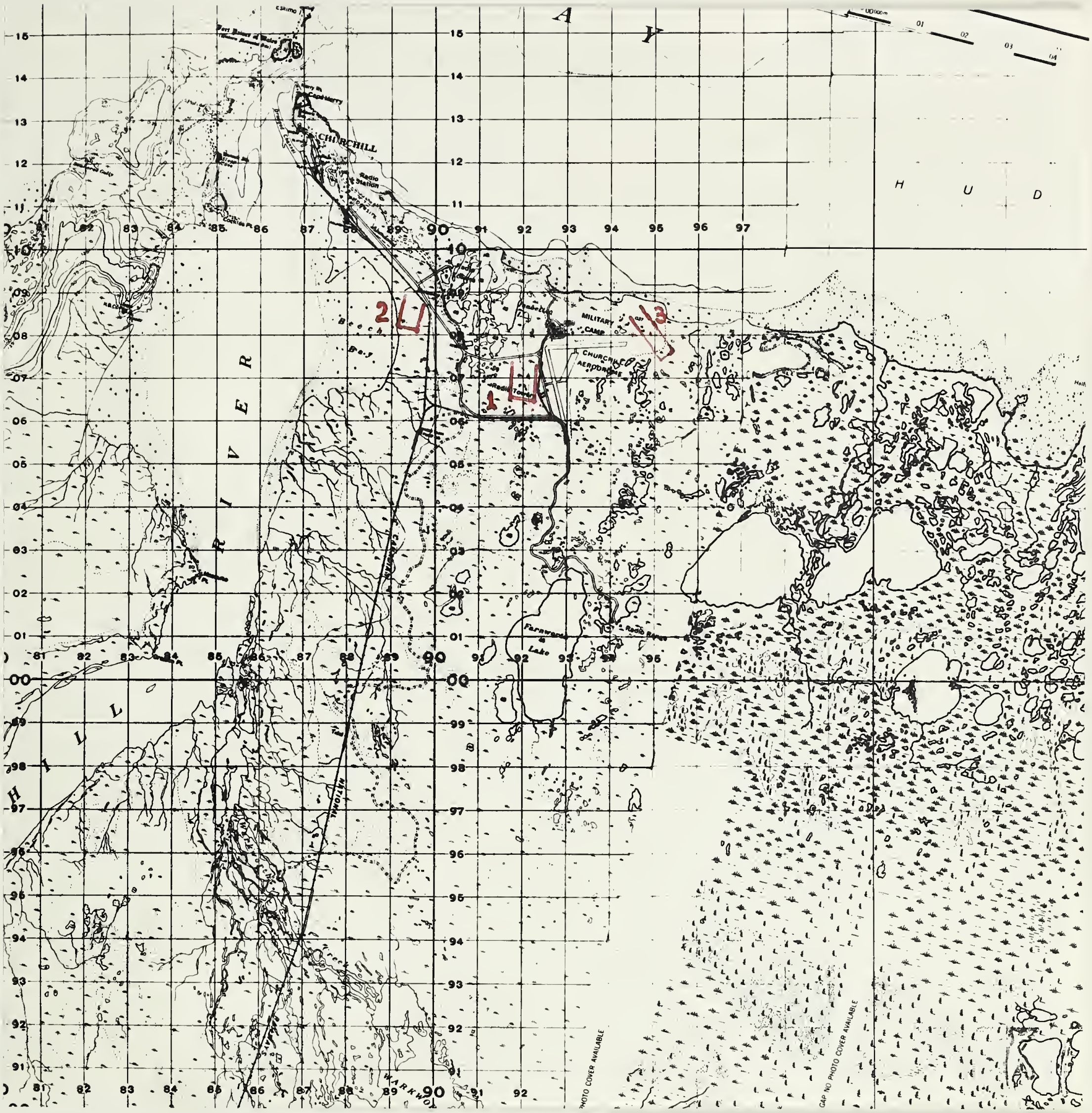


Figure 23: Map showing the location of plots treated with DDT aerosols.

gallon per minute.

Prior to the liberation of the insecticide, dipper counts of the mosquito larval population at selected locations were made; these were repeated at intervals after the treatment and a comparison of the figures obtained was used for estimating the mortality at varying distances from, and to the leeward side of the line of release of the insecticide. No chemical or physical estimates of the DDT deposited at varying distances, nor of the droplet size spectrum of the aerosol were made, but the nozzle temperature was kept at 300 - 325°F. to minimize the charring which occurred at the recommended temperature of 450°F., and to give a rather coarse droplet size in view of the prevailing high wind speeds.

Experiment 1.*

The base line for the plot used in this experiment was set out with ends determined by the map references 917066 and 922065. The sides of the plot ran north and south, and east and west, as the prevailing winds for a few days prior to the marking out had been approximately southerly in direction. The terrain was level tundra meadow, with a large proportion of the area taken up by shallow and for the most part rather indefinite pools in which the mosquitoes A. punctor, A. nigripes, and A. nearcticus were breeding. The population, although well distributed was nowhere very heavy. This distribution of water bodies, while it greatly facilitated the selection of dipping sites, proved ultimately, in this particular instance, to render

* This experiment was conducted by Mr. W.C.McDuffie to whom I am indebted for permission to interpret and use these results.

the effects of evaporation very serious. A general view of the area is shown in figure 26.

The plot was being used for breeding purposes by various birds, chiefly plovers and curlews. These suffered no direct adversity from the experiment.

Dipping stations were marked out in three equally spaced lines running north from the base line, and at intervals of 50 yards from this, the stations furthest from the base line being at a distance of 550 yards from it. Lines were numbered 1, 2, and 3, from east to west. The layout of the plot and the dipping stations is shown in figure 24. 400 cc. dippers were used, and ten dips were taken at each station at each population estimate. The average number of larvae obtained per dip in the pretreatment estimate made on June 16 was 1.06; these were all in the third or fourth instar; the results are set out in detail in the first group in table 2.

The insecticide was dispensed from 10.0 to 11.30 a.m. on June 18. The weather was fine, with light cloud; wind SSE, the recorded speed by anemometer on top of an adjoining ridge to the east of the plot was 15 m.p.h.; wind speed at the plot was appreciably less than this and was estimated at 10 - 12 m.p.h. The shade temperature during the treatment rose from 58 - 63^{o}F., and it appeared from the behaviour of the insecticide cloud, which moved close to the ground and remained visible for a distance of some 150 - 200 yards, that inversion conditions prevailed. The generator was actually in operation for 75 minutes, one stoppage being necessary to change a choked filter, but for only 48 minutes was the emission actually over the

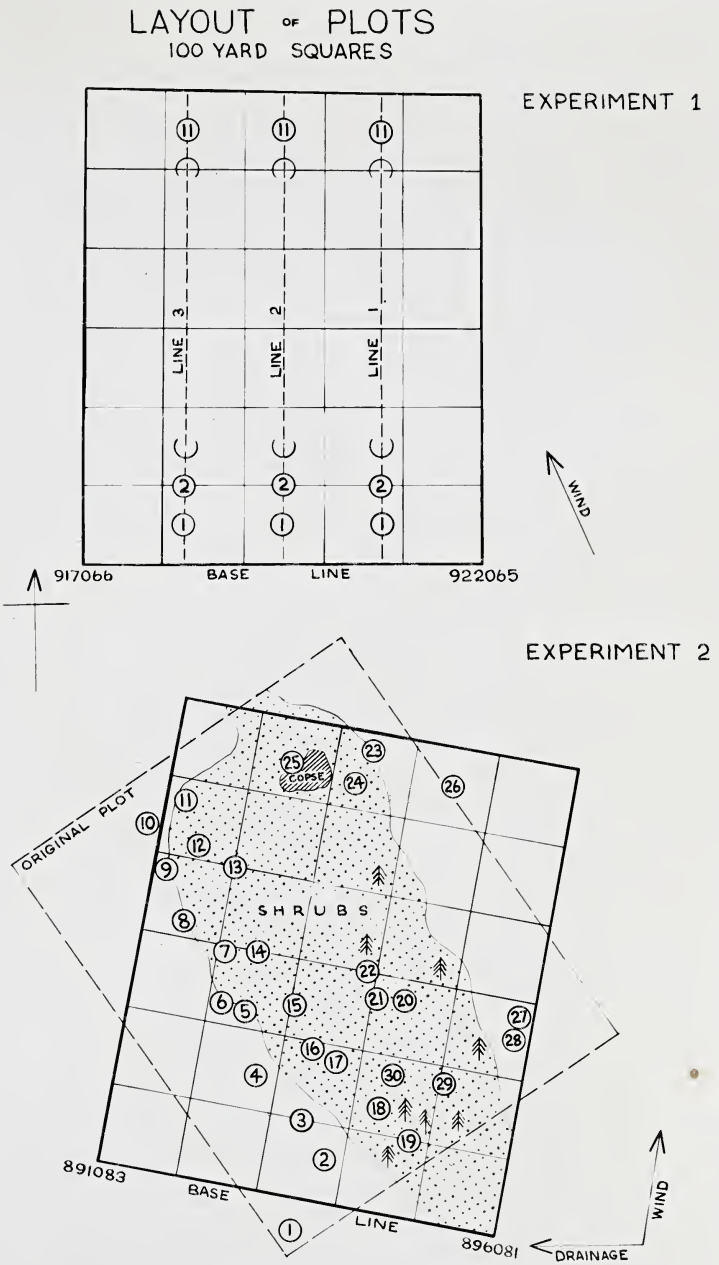

LAYOUT OF PLOTS
100 YARD SQUARES
EXPERIMENT 1
LINE 3
LINE 2
LINE 1
WIND
917066
BASE LINE
922065
EXPERIMENT 2
ORIGINAL PLOT
COPSE
SHRUBS
891083
BASE LINE
896081
DRAINAGE
WIND

Figure 24.

Figure 25: Snowmobile with amphibious trailer, carrying aerosol equipment.

Figure 26: A general view of the area of experiment 1.

observed plot, the remaining time being spent in turning at either end of the base line. During these 48 minutes, 14 gallons of emulsion were consumed; this represents a total application of 5.4 lbs. DDT or 1.08 lbs. per hundred yards of base line. If it is assumed that virtually all of this DDT is deposited within the observed area, the calculated dosage then becomes 0.087 lbs per acre.

During the emission period the generator was towed at a little over 2 m.p.h.; beginning at the east end of the base line, three complete round trips to the west end and back to the east end were made. Walking down wind from the generator, the smell of xylene could be detected wherever there was visible cloud. At the end of the emission a distinct oil film was detectable on the surface of pools up to at least 200 yards from the emission line; at 50 yards this was so pronounced that a photograph was secured and is reproduced as figure 27. A short distance from the baseline, dolichopodid flies were seen to be in difficulties on the surface of the water quite early in the treatment, but towards the conclusion of this, dancing clouds of newly emerged midges at 400 yards from the base line seemed quite unaffected.

The first population estimate after treatment was made approximately 24 hours later on June 19. Weather conditions remained much the same as at the previous count, except that the barometer was now falling rather rapidly. The counts obtained at this estimate appear in the second group in table 2. A superficial examination of the area showed no conspicuous reduction in larval population beyond 50 to 100 yards down wind

TABLE 2. Population estimates and percentage mortalities at varying distances from the base line.

Station number	Distance from base line, in yards.	Count before treatment 16.VI.47 (No pupae)			Count 24 hours after treatment 19.VI.47						Count 72 hours after treatment 21.VI.47 (line 1 notes lost in transit)				
		Line 1, larvae	Line 2, larvae	Line 3, larvae	Line 1 Larvae	Line 1 Pupae	Line 2 Larvae	Line 2 Pupae	Line 3 Larvae (No pupae)	Apparent per cent mortality	Line 2 Larvae	Line 2 Pupae	Line 3 Larvae	Line 3 Pupae	Apparent per cent mortality
1.	50	6	9	14	0	0	18	0	8	10	13	2	0	0	25
2.	100	10	25	0	10	4	28	0	4	9	24	6	5	0	-10
3.	150	0	15	10	2	0	29	9	11	-68	22	12	3	0	0
4.	200	11	10	20	5	0	5	0	9	54	5	4	11	0	39
5.	250	7	10	12	8	0	4	1	9	45	7	5	11	6	23
6.	300	11	7	16	10	0	10	3	11	6	12	10	2	0	13
7.	350	8	5	19	8	0	40*	0	64*	-250	dry		dry		-
8.	400	9	8	46	20	4	10	3	20	8	12	6	0	200*	-151
9.	450	8	7	dry	11	5	8	1	dry	-19	10	4	dry		-77
10.	500	7	2	9	12	1	7	0	10	6	7	2	10	10	-120
11.	550	7	dry	1	7	0	dry		7	-75	dry		9	8	-1300

*Based on less than 10 dips: pool drying up.

Figure 27: Oil film on surface of pool 50 yards from base line in experiment 1.

Figure 28: A general view of the grassy area in experiment 2.

from the base line; many living larvae were seen considerably closer than this, although here there were also dead and moribund mosquito larvae and dead water beetles and caddis larvae. At stations 7 in lines 2 and 3, the pools had dried up to such an extent that it was not possible to take the full ten dips, and a similar drying up may account for the capricious figures at other stations. As expected from the direction of the wind, mortality in line 1 did not extend appreciably beyond 100 yards from the base line. There were many pupae in the counts at this estimate.

A final population estimate was made on the morning of June 21, 72 hours after the treatment. Weather conditions were very different; 0.08 inches of rain fell on the morning of the observations, humidity was much higher, the sky was overcast, and the barometric pressure still lower than at the 24 hour count. The figures obtained are recorded in the third group in table 2. and are no less capricious than those obtained at the previous count; figures for line 1 were unfortunately lost in transit. By this time further pools had so dried up as to prevent ten full dips being taken, notably at stations 8 and 9 in line 3; clearly this drying up had not been offset by the small amount of rain which had fallen. There was a much greater proportion of pupae appearing in these counts.

The first mosquito pupae taken in the Churchill area during this season were found on June 16, the date of the first population estimate. In view of the two day interval between this estimate and the treatment, the assumption has been made that some of the pupae appearing in the second and third

estimates had already pupated before the application of the insecticide. Considering also that the whole experiment took place during the very beginnings of the pupation period for the species concerned, it has been further assumed that the pupation rate throughout the experiment was uniform. Working on these two assumptions, in calculating percentage mortalities the pupal figures obtained in the post treatment counts were weighted, each pupa counting as 1/3 of one larva in the 24 hour count, and as 3/5 of one larva in the 72 hour count. This was done in order to give a picture of the effect of the insecticide on the larvae, uncomplicated by the known greater resistance of pupal mosquitoes. The apparent percentage mortalities given in table 2 were obtained by this method.

Discussion: It is clear that the dosage employed was too low to give effective larval control over a useful area, although the results obtained, in spite of their capricious nature, definitely represent a serious under-estimate of the actual mortality.

During the period between the first and second population estimates, temperatures were high and humidities low, while wind speeds were moderate to high, and precipitation was nil. During the day of treatment, the humidity actually reached the lowest figure recorded during the period of work at Churchill, and the saturation deficiency reached a maximum for this same period at 8.97 mms. of mercury, and was continually high throughout the period. These extremely drying conditions would naturally be expected with continual southerly or land breezes, and operating as they did, for an undesireably long

[illegible]

[illegible]

[illegible]

[illegible]

interval on highly dispersed water bodies, they clearly brought about a remarkable concentration of larvae from wide areas into smaller and smaller pools. Such a concentration naturally shows itself as an increased apparent population, when this is sampled by the dipping method. This apparent increase offset, and in some instances more than offset, the reduction brought about by the treatment. No other explanation for these figures can be adduced; first and second instar larvae were not found.

The very great variation in apparent mortality recorded at different stations is directly attributable to the variation in mean depth of the separate pools and water areas. The fact that apparent percentage mortalities of 54 per cent at 200 yards and 45 per cent at 250 yards were recorded, can only be explained on the assumption that the insecticide did cause significant kills; the possible action of predators can be discounted by virtue of their small numbers here, and the general absence of any conspicuous reductions in population due to them in this locality.

The lapse of a further two days between the 24 hour and 72 hour population estimates allowed further evaporation to occur, although conditions were not then so severe. That this is the correct explanation is supported by the following facts: that there is good correlation between the 24 hour and the 72 hour figures, the latter being the more extreme; that those stations which were nearly dry gave the conspicuously higher counts; and finally, that some stations had dried up completely at the 24 hour count, and still more after 72 hours.

If the 24 hour count population figures are adjusted for evaporation on the basis of station 10 line 2, which shows the highest per cent increase of stations where insecticide mortality would be expected to be small, the mortalities shown in the graph, figure 31, are obtained. These are considered to represent a reasonably close approximation to the true figures.

On the basis of the results obtained in this experiment, it was decided to run a second experiment at a higher dosage, allowing a smaller time interval between population estimates, and particularly between the pretreatment estimate and the treatment.

Experiment 2.

This experiment was run from a base line between the map references: 891083 and 896081. As it was proposed to release the insecticide on this occasion in the evening, and the wind on the three previous evenings had been SE and SSE, the base line was marked out on a bearing of 55°, and 600 yard side lines were marked out from either end of this. The terrain here was flat, with numerous discrete pools, which were rather scarcer towards the higher, shoreward, or eastern boundary. The central portion of the area selected was densely covered with willow and birch shrubs to a height of 2 to 3 feet. Figures 28 and 29 show typical parts of the open and shrub covered areas. Drainage was towards the west, into the Churchill River. There were scattered spruce and larch trees on the higher ground, a small copse of these towards the northern

end, and many rocks. Although somewhat scanty in the higher area, the mosquito larval population here was considerably higher than in experiment 1, and its extent was more clearly circumscribed by the well defined pools. The most important species were A. punctor, A. campestris, and A. flavescens, and these were present in second third and fourth instars. A species of Chaoborus was also present in considerable numbers at stations 2 and 5. There were many fish and frogs in the pools; none of these were observed to suffer any direct harm as a result of the insecticide.

Thirty dipping stations were marked out within this area. These were selected with different degrees of exposure; number 11, a typical station is shown in figure 30. The larval population at each of these stations was estimated by dipping with 600 cc. capacity dippers. Five dips were taken at each station by each of two independent observers. When more than 12 larvae were obtained in a single dip, this was recorded as '12 plus'. The pretreatment count at the first 19 stations was taken on the evening of June 19, and at the remaining 11 stations mostly in the higher area, on the morning of June 20. The detailed counts are shown in the first group in table 3; the average number of larvae per dip was 3.14.

The insecticide was dispensed from 10.50 a.m. until 3.30 p.m. on June 21, using the same equipment and material as in experiment 1, but during the second half of the run it was found necessary to tow the generator once along the base line, stopping for a calculated period at 25 yard intervals. This change was made on account of the very rough nature of the ground

Figure 29: A general view of the shrub covered area, experiment 2.

Figure 30: Station 11, a typical dipping station.

TABLE 3. Population estimates and percentage mortalities at varying distances from the base line. Experiment 2.

Station number	Distance from base line in yards	Count before treatment 20.VI.47 Larvae.	Count 24 hrs. after treatment 22.VI.47			Count 48 hrs. after treatment 23.VI.47			Characteristics of pool
			Larvae	Pupae	Percentage mortality	Larvae	Pupae	Percentage mortality	
1.	30	26	23	-	-	20	-	-	Open, grassy
2.	60	53+	2	1	95+	-	-	100	Open, grassy
3.	100	27	-	-	100	-	6	85	Open, some shrubs
4.	140	35	21	-	33	5	-	86	Slightly screened
5.	220	49+	1	1	96+	1	1	97+	Slightly screened
6.	230	40	2	-	94	5	-	87	Slightly screened
7.	290	29	12	1	51	-	4	91	slightly screened
8.	320	51	15	4	62	-	6	92	Open, grassy
9.	380	17	7	4	40	2	2	81	Open, grassy
10.	430	34	14	2	50	14	5	51	Slightly screened
11.	470	59	20	-	62	9	-	85	Heavily screened
12.	420	32	7	-	75	3	5	80	Slightly screened
13.	400	62+	48	-	13+	10	-	84+	Slightly screened
14.	300	23	1	-	95	-	-	100	Slightly screened
15.	240	26	7	-	70	3	-	88	Heavily screened
16.	190	23	3	-	85	3	-	87	Heavily screened
17.	180	27	13	-	45	9	-	67	Heavily screened
18.	130	33	12	1	57	13	1	58	Heavily screened
19.	100	20	2	2	83	-	-	100	Heavily screened
20.	270	28	7	-	72	8	-	71	Slightly screened
21.	270	21	10	-	46	-	-	100	Slightly screened
22.	300	6	3	-	43	1	1	72	Heavily screened
23.	580	23	14	-	30	2	8	68	Open, grassy
24.	530	51	7	38	43	6	24	57	Open, grassy
25.	540	32	22	-	22	15	1	51	Heavily screened
26.	550	27	6	4	67	4	3	78	Open
27.	280	22	-	2	95	2	7	70	Slightly screened
28.	250	16	3	4	65	-	7	71	Slightly screened
29.	180	31	12	-	56	2	-	94	Heavily screened
30.	180	18	2	-	37	1	-	94	Heavily screened

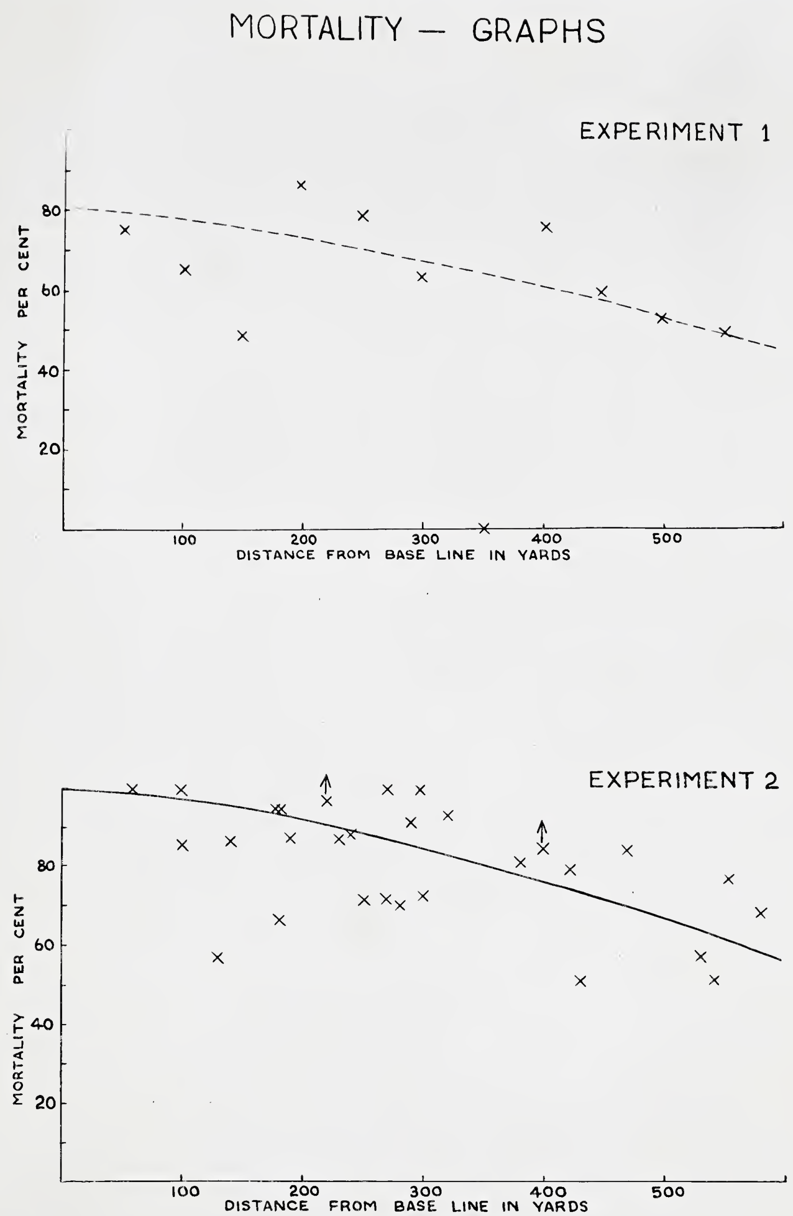
and was found to be far more satisfactory, reducing wear and tear on machines and personnel to a minimum, and virtually eliminating end effects due to time taken in turning. A reduction of the distance between stops to 10 yards would be preferable, at least in experimental work, as the lateral spread is not very great, when meteorological conditions are suitable for aerosol application. The effect of an appreciable wind shift during operation in this manner would, of course, be far more serious, but such an eventuality did not arise. The greater time taken to dispense the material in this experiment was partly due to the greater amount of material, and partly to mechanical difficulties with the generator. There were numerous stoppages; three on account of choked filters, and one on account of engine trouble, appeared to have been unavoidable with the equipment as used. The longest continuous operation obtained was 25 minutes. These difficulties may have been accentuated by the rather violent movement of the vehicles.

The wind in the early morning was NW which would have been very suitable for spraying from the north end of the plot. By the time the equipment was assembled at site, however, this had changed to SW, and a new base line was set out at 45° to the original line passing through the two 100 yard marks N and E respectively of the SW corner of the original plot, and with its centre mid way between these. The new plot included all the dipping stations except no.1. which fell south of the centre of the base line, and no.10 which fell just outside the western side line at about the 500 yard mark. The layout of the initial and the ultimate plots, and of the dipping stations is shown in figure 24.

The sky was overcast almost throughout the treatment; the wind was blowing from a direction slightly west of that of the plot during the first half of the treatment, but veered to slightly east of this direction during the second half. There was thus a tendency for the dosage on marginal dipping stations to be low, and for that on the central stations to be high. Wind speed recorded on the ridge by the airstrip was 10 m.p.h., that at the site was considerably less and was estimated at about 4 m.p.h., strengthening somewhat later to about 6 m.p.h. From the behaviour of the cloud which clung closely to the ground, rather poor inversion conditions prevailed. Air temperature rose from 58 to 65^{o}F. during the treatment; humidity was moderate, and barometric pressure rather low, and falling.

The generator was in operation over the plot for a total time of 125 minutes, during which time 47 imperial gallons of emulsion were dispensed; this figure corresponds to 18 lbs. of DDT or 3.6 lbs. per hundred yards of base line. Assuming that virtually all this material was deposited within the test plot, this means an average deposition of 0.29 lbs. DDT per acre.

The cloud of insecticide could be seen clearly for 200 to 250 yards, and appeared to be settling down nicely; after two runs a definite film was visible on pools at 100 yards, but there were still quite a number of adult mosquitoes on the wing in the cloud. Walking in the aerosol cloud down wind from the generator, xylene could be smelled distinctly for a distance of 150 yards; from 100 yards onwards, the odour of DDT became noticeable as well, and this persisted up to a total distance from the machine of at least 400 yards. Before the end of the



MORTALITY — GRAPHS
EXPERIMENT 1
MORTALITY PER CENT
80
60
40
20
100
200
300
400
500
DISTANCE FROM BASE LINE IN YARDS
EXPERIMENT 2
MORTALITY PER CENT
80
60
40
20
100
200
300
400
500
DISTANCE FROM BASE LINE IN YARDS

Figure 31.

treatment, many adult insects, mainly mosquitoes and other diptera (Tipulidae, Dolichopodidae, Scatomyzidae), had been knocked down on to the pool surfaces, and some mortality of mosquito larvae could be detected.

The first population estimate after treatment was made 24 hours later, on June 22. The weather conditions were very much the same as during the treatment, but nearly 0.1 inches of rain had fallen since the initial estimate. The dilution resulting from this is reflected in the reduced population in the untreated check station (no.1), and in calculating apparent percentage mortalities the counts at this estimate have accordingly been increased in this proportion, viz: 26/23. While carrying out this estimate the smell of DDT was clearly noticeable when walking through thick shrubs, presumably from a deposit brushed off the leaves. Partial elutriation of this deposit into the pools by rain may have influenced the results obtained. Many dead sawflies, craneflies, midges and dolichopodid flies were seen on the pool surfaces during this count.

As there were virtually no pupae in the majority of pools at the initial estimate, pupal figures obtained in the 24 hour count were, on the assumption of a uniform pupation rate, weighted as one half larvae in calculating mortalities. Detailed figures are set out in the second group in table 3. The mean percentage mortality for the whole area after 24 hours was not less than 63 per cent.

A final population estimate was made 48 hours after the treatment, on June 23. The temperature was then much lower and the humidity much higher than at the previous two estimates, but

the barometer was rising rapidly, the wind speed had increased, and there had been no appreciable rain since the 24 hour estimate. The amount of water in the pools appeared to be approximately the same as that found at the beginning of the experiment; this is unfortunately not shown in the count on station 1, as this had been upset by contamination with oil from a passing vehicle. Larval counts in this estimate were accordingly taken at their face value, while pupae were valued at 2/3 larvae. Detailed figures are given in the third group in table 3, and a graphical interpretation of these in figure 31. The mean percentage mortality for the whole area after 48 hours was not less than 81 per cent.

Discussion: At the dosage used in this second experiment a useful mortality was obtained over the whole of the plot observed. It would have been of considerable experimental advantage, however, to have extended entomological observations to a greater depth from the base line, so that 50 per cent mortality at least were included within the observed area. 1000 yards would have been a more suitable figure. It appears from a consideration of the graph (Fig.31) that at this dosage, 50 per cent mortality could be expected at a distance of about 700 yards from the emission point, and that to obtain better than 90 per cent mortality over an area of country under these conditions, it would be necessary to traverse this at right angle to the wind direction at intervals of about 500 yards.

Only one living specimen of *Chaoborus sp.* was taken in the 24 hour count (station 5), and none at all in the 48 hour

estimate. This would suggest 100 per cent mortality for this species at 220 yards, and consequently, that DDT is no less toxic to these larvae than it is to the larvae of Aedes.

The low mortality figure for station 10 is attributable to the fact that this station was outside the plot boundary. The absence of any marked difference in mortality between the open and the heavily screened dipping stations would seem to indicate that in spite of the relatively large droplet size, the material was showing true aerosol characteristics.

Weather conditions, as in the first trial were remarkably favourable: there were only about six days during this season when both the mosquito larval population and the meteorological conditions were suitable for this method of dispersing insecticides. The most important adverse meteorological factor is high wind speed. This coupled with the slowness in action would be the main obstacles to the successful operation of this equipment here. A single machine in 1947, working 16 hour days whenever conditions were suitable, would have treated only a little over three square miles. With the existing mechanical shortcomings, even this figure could not have been approached, and in any event, the area would have to be selected for its traversable nature. A generator of greater capacity as used by Brescia and Wilson (11) or a battery of such generators, to permit continuous movement at about 4 m.p.h. would be a necessary development.

The results obtained in both experiments are not in disagreement with those obtained in, or predictable from similar work elsewhere (25,33,58), so that there would not appear to be

any other special problems with regard to this method of insecticide application at high latitudes. Rather the general absence of very broken country would tend to favour the predictable deposition of an aerosol.

There is some evidence that high wind difficulty is partly a local effect only, resulting from sea breezes. Further inland, at least south of the tree line, more moderate wind speeds are to be expected, and in such areas, aerosol application should prove easier. It is relevant to note that both the adult mosquito and the aerosol, operate more satisfactorily at the lower wind speeds.

5.1.2. A test of the Besseler Aerosol Generator against Adult Mosquitoes:

An experiment was performed during the period July 1 to July 3, 1947, to test the usefulness of the Besseler aerosol generator against adult mosquitoes in wooded country. Although the experiment was not a successful one, in that no very real test of the equipment resulted, nevertheless it proved of some value in demonstrating some of the difficulties which would face routine control measures equally with experimental work, in employing this generator in country such as that around Churchill.

Two provisional plots for this experiment were selected on July 1. The first of these was in the vicinity of Farnworth Lake, to the south of Churchill, and could be treated from a vehicle on the Radio Range road, given a suitable southwest wind. The second was a strip of wooded country running north and south

about a half a mile beyond the eastern end of the east-west runway of the Churchill aerodrome. The wind on the morning of July 2 being from the south, it was decided to use the second of these plots for a test the same evening. Meteorological reports indicated that the wind might be expected to remain in the south, and that the wind speed should moderate. Detailed meteorological data were recorded.

The locality was visited during the afternoon, and a 400 yard base line was set out on a bearing of 100° from the point 951074. This gave a plot depth of nearly 1500 yards, the first 150 yards being open country, and the remainder woodland, mostly rather stunted spruce. The general appearance of the terrain is shown in figure 32. A wooded area some 500 yards west of the test plot was selected as the control area, and an alighting rate figure of 31 was obtained here, as compared with 33 for the wooded area of the test plot. Each figure is the mean of eight readings. All observers throughout the experiment wore one of four standard and comparable mosquito repellents on the face and hands.

At 6.00 p.m. the wind was reported to be moderating, and from the same bearing, but the temperature had dropped considerably. It was decided to run the test, although conditions were far from ideal, truly ideal conditions being very rarely obtained at Churchill. By the time the equipment had been assembled the wind bearing had dropped 50° to 140°, the speed, though rather high, was satisfactory, but the temperature had fallen to 56°F. and rain threatened. To compensate for the wind shift, the base line was reset to a bearing of 50° from the point 952075. This change resulted in the first 400 yards only of the plot depth

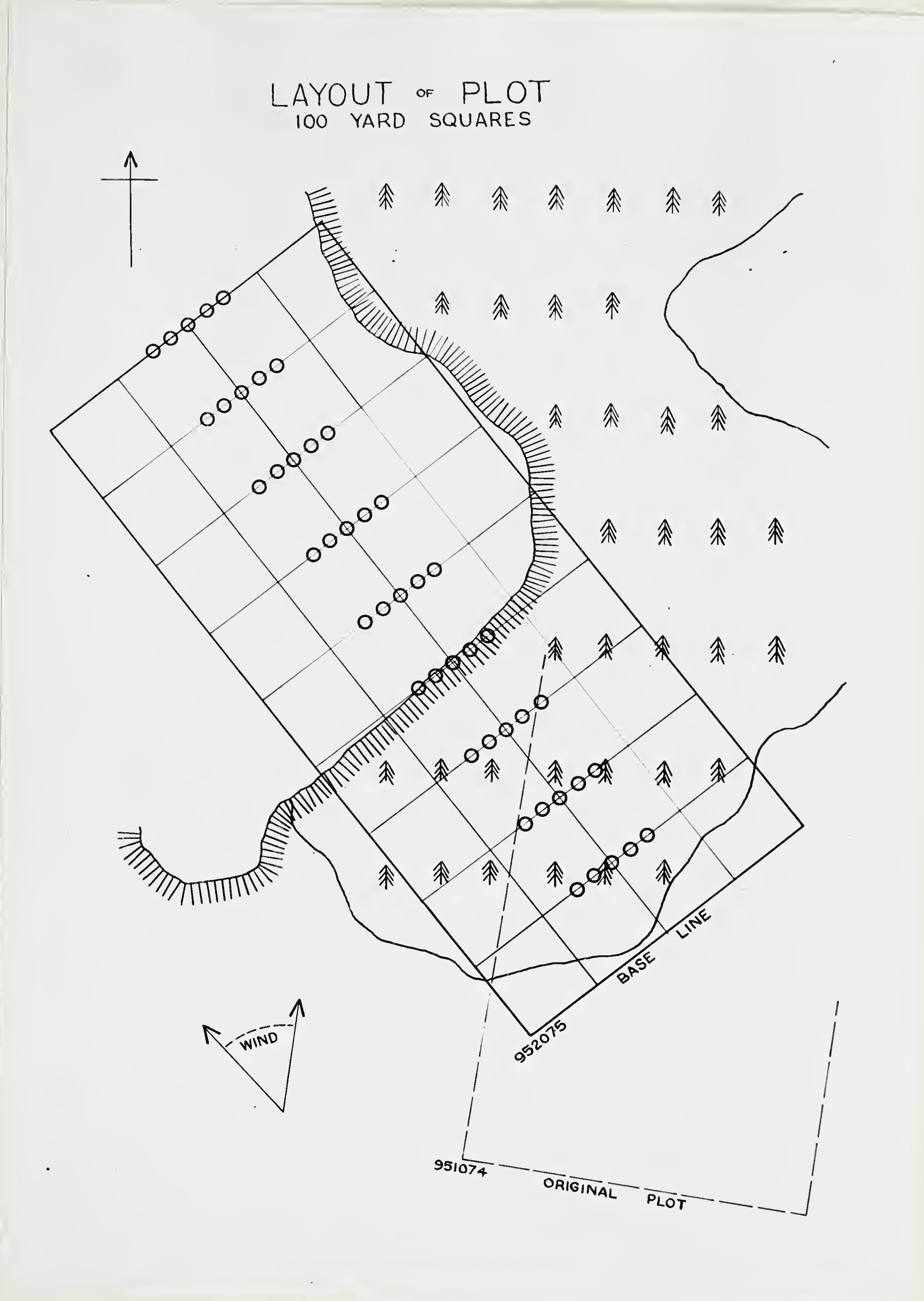
being in wooded country. At about 400 yards, a rocky cliff, some 30 feet in height, led up on to flat, higher, rocky open country, where the wind speed was considerably greater, extending back to the shore of Hudson Bay.

Observers were stationed at 100 yard intervals from the base line to a depth of 900 yards. Each observer took five readings, the individual readings at intervals of 25 yards along the central 100 yard portion of the plot at the distance at which the observer was stationed (Fig. 34). These five observations were taken immediately before the discharge of the aerosol commenced, and were repeated immediately after this was completed. Nil readings were obtained both before and after the release of the aerosol at all stations more than 400 yards from the base line; i.e., at all stations on the open and higher rocky area. Readings obtained at other stations are recorded in table 4. The mosquito species involved were A. nigripes, with some A. nearcticus.

The Besseler generator was mounted in a tracked amphibious trailer and towed by an amphibious weasel (Fig. 33). The insecticidal material employed in the generator was a 10 per cent W/V solution of DDT in fuel oil with added Williams' Red dye. The coil temperature employed was 300°F., equivalent to a mass mean droplet diameter of 20 microns and a discharge rate of 35 imperial gallons per hour. The equipment was moved along the base line, stopping at each 25 yards distance until the expiry of a three minute period from the time of leaving the previous stop. The total emission time was thus 48 minutes, during which period 21.5 gallons of insecticide were used. Since

Figure 32: A general view of the terrain with amphibious weasel in the foreground.

Figure 33: The Besseler generator in an amphibious trailer.



LAYOUT OF PLOT
100 YARD SQUARES
BASE LINE
952075
WIND
951074
ORIGINAL PLOT

Figure 34.

TABLE 4. Mosquito alighting rates at various distances from the base line at different times after treatment.

Distance from base line in yards	6 hrs. before treat-ment	Immediately before treatment	Immediately after treatment	24 hours after treatment
100	-	0,1,6,5,10	0,0,0,0,1	48,59
200	-	0,1,0,1,1	0,0,1,0,0	39,54
300	33	2,3,0,1,1	0,0,0,0,0	- -
350	-	-	-	6,12
400	-	0,0,2,0,1	0,0,0,0,0	41,45
Check site (untreated)	31	-	-	35,37
Average alighting rate	32	1.75	0.1	37.6

All counts beyond 400 yards were nil.

this was expended over an actual front of 375 yards, this gives a figure of 5.73 gallons of solution, or 5.73 lbs. of DDT per 100 yards of front. Assuming practically all of this material to be deposited on the observed area, this would give a mean figure of 0.31 lbs. DDT per acre.

The wind bearing during the emission period fluctuated between 150 and 170°, with a speed between 14 and 20 m.p.h. in the open, and 9 - 10 m.p.h. in the wooded area. No readings were taken on top of the rocky flat. The barometer was falling rapidly, and the air temperature dropped from 56 to 51°F. during the experiment, the relative humidity rising from 81 to 94 per cent. The temperature gradient between one and two metres ranged from 0 to 0.12°C, giving a parameter R (8) value of 1.14 to 1.13. The sky was very heavily overcast almost throughout the test, and there was some very light rain.

Emission started at 7.22 p.m., and this, together with the conclusion of the emission at 8.10 p.m., was signalled to the observers in the plot by Verey pistol. The aerosol was emitted from all four nozzles of the generator, the cloud drifting satisfactorily, though rather rapidly, into the woods. The observer at the 100 yard point reported the cloud visible after three minutes from the start of the emission, and the observer at 200 yards after 15 minutes. No observer on top of the rocky flat reported the cloud visible at any time, but the smell of the aerosol was noticed independently by observers at 800 yards and 900 yards, about 4 minutes after the start of the emission. No mechanical difficulties were encountered with the generator. This experiment clearly demonstrated the

disadvantage in experimental work of covering the area by intermittent stops on s single run; wind shift during the emission was such that from the last two or three stops at the NE end of the line, none of the aerosol covered the plot at all.

A final survey of the adult mosquito population was made at 3.0 p.m. on July 3, the figures obatined are recorded in table 4. Mosquitoes were active throughout the area, including the top of the rocky flat, and were very intent on feeding. The barometric pressure had fallen still further, but the wind speed was less and the humidity higher; other meteorological conditions were unchanged from the time of treatment.

Discussion: It is not possible to say at all definitely how much of the reduction in immediate biting rate during the experiment was due to the action of the insecticide, and how much to adverse meteorological conditions. The fact that later in the season high alighting and biting rate figures were obtained with air temperatures down to 50°F. and even below this, with strong winds in addition, supports the view that the insecticide was the main cause of the reduced alighting rates. Observations in other experiments on plots up to one mile square sprayed from the air (McDuffie et al, Goldsmith et al) and also general observations on the habits of the species of mosquitoes involved here, indicate that complete repopulation of a plot this size, could readily occur within 24 hours.

On the other hand, although the figures indicate a mean reduction in alighting rate of 94 per cent over the first 400 yards of the plot, the percentage mortality obtained in the total population was probably very much less than this. David

and Bracey (17) have shown for droplets of 10 microns and less, that impact on the insect is brought about by movements of the insect rather than of the droplet. This probably remains in large measure true for droplets of the size used in this experiment, so that mortality among the resting mosquitoes, which at the time of treatment constituted a very large proportion of the total population, would have been very small. These resting mosquitoes were in fact probably very largely responsible for the rapid build up of a large active population after the treatment.

The momentary and local smell of the aerosol which was detected on top of the rocky flat may be taken to indicate either that the high wind speed was inimical to uniform distribution, or that the wind direction being normal to the rocky cliff resulted in up currents being set up above this, which carried the bulk of the aerosol well clear of ground level. Probably a combination of these factors was operating.

The absence of mechanical difficulties, and the greater discharge rate make the Besseler generator more satisfactory equipment for use in this area than the model of the Hochberg-Lamer generator employed in the earlier tests against mosquito larvae. The discharge rate of the Besseler generator, however, is still too low to permit the necessarily large area to be treated during the very short time when meteorological conditions may be expected to be suitable.

5.1.3. An Evaluation of some Insecticides against the immature stages of Blackflies:

Introductory:

Apart from work with miscible oils and pyrethrum preparations (24,80,81) which gave consistently uneconomic control, very little previous work has been done with insecticides against immature blackflies. In 1945 Fairchild (19) and Fairchild and Barreda (20) demonstrated that a number of species of *Simulium* occurring in Gautemala could be effectively controlled by the application of a DDT emulsion to give a concentration of 0.1 parts of DDT per million parts of water for a period of one hour, and that both a solution of DDT in a turpentine-kerosene mixture, and a suspension of DDT in water with a wetting agent were equally effective. Garnham and McMahon (22) have reported the local eradication of *S. neavei* Roubaud in Kenya colony in 1946, using the much higher concentrations of 2 to more than 5 parts of DDT per million parts of water for exposure periods of 30 minutes. At these dosages mortality among fish and other animals was considerable. Steward (55) found that in the laboratory, 0.25 p.p.m. DDT for one hour caused almost complete mortality of *Simulium* larvae, while Gammexane gave similar results at 0.125 p.p.m.

For purposes of comparison of these various exposure times and concentrations, it may be assumed that the time- concentration curve for any given mortality approximates to an hyperbola over the small range considered (15), and hence that:

[illegible]

[illegible]

[illegible]

concentration x time, is a constant.

Dosages in these experiments may then be expressed as products of concentrations in parts per million and exposure time in minutes as follows:

Fairchild and Barreda - DDT		6 p.p.m./mins.
Garnham and McMahon - DDT	60-more than 150	p.p.p./mins.
Steward - DDT		15 p.p.m./mins.
Gammexane		7.5 p.p.m./mins.

It was decided to attempt to confirm these results under the conditions at Churchill, to compare the effect obtainable with some other insecticides, and finally to explore the possibility of reducing the time of exposure required. In view of the great number of streams which would have to be treated for effective control in an area such as that around Churchill, the ability to do this would be of very great advantage. In addition it was hoped to obtain further data on possible toxic effects on eggs and pupae.

The work may conveniently be reported in the form of seventeen experiments grouped into three main categories; two experiments involving aerial application of insecticides, fourteen involving direct application of insecticides to streams, and one experiment in which the pupal stage was treated with insecticides in the laboratory. Accounts of these experiments numbered serially throughout, from one to seventeen, are given below. The first two experiments in the second group are reported in somewhat greater detail than the remainder, since an attempt was made in these to secure quantitative estimates of populations and mortalities; this was found to be impracticable, and qualitative estimates only, were attempted thereafter. The predominating species of blackfly in all experiments was

Simulium venustum; where other species were important, these are mentioned in the account of the experiment concerned.

The following insecticidal preparations were employed in this work:

1 - trichloro - 2,2 - bis(p-chlorophenyl) - ethane(DDT):

5 and 10 per cent W/V solutions in fuel oil with 0.5 per cent Williams' Red dye added, the latter with Velsicol A.R.50 as auxiliary solvent.
25 per cent emulsion concentrate with 65 per cent Xylene and 10 per cent Triton X-100.
50 per cent wettable powder (Deenate 50W).

1,2,3,4,5,6 - hexachlorocyclohexane (Benzene hexachloride):

An emulsion concentrate supplied by Canadian Industries Limited, containing 5 per cent gamma isomer.

Chlorinated Camphene (Toxaphene, 3956):

25 per cent emulsion concentrate with 65 per cent xylene and 10 per cent Triton X-100.

Chlordane (1068):

25 per cent emulsion concentrate with 65 per cent xylene and 10 per cent Triton X-100.
10 per cent solution in Velsicol A.R.50 and fuel oil.

Pyrethrum - piperonyl butoxide (PPB):

Dodge and Olcott's Pyrenone emulsion concentrate (T.143) containing 10mgms. pyrethrins and 100mgms. piperonyl butoxide per cc.

Aerial spraying Experiments:(1)

Two streams infested with blackfly larvae flowed in part through three plots marked out for aerial spraying trials against mosquito larvae and adults. A blackfly survey of these streams was made before the spraying to ascertain its effect on the blackfly larvae. The first of the streams flowed through the first aerial spray plot only, for a distance of about 900 yards.

The first half mile of the second stream was in the second aerial spray plot, described under experiment 2, the

second half mile in the third aerial spray plot, and only the last half mile in the first aerial spray plot. Eight observation stations were marked out in the first stream, and five in the last half mile of the second; at each of these stations there was a moderate to heavy population on the afternoon of June 27. No pupae were present at this time. The mean depth of each stream, and the rate of flow were estimated at the same time, the latter by timing a surface float over a measured distance to get the maximum speed, and calculating the total flow from the formulae:

$$V_a = 2/3.V_m \quad \text{(approximately)}$$

$$\text{and:} \quad \text{Flow} = V_a.A$$

where V_m is the measured maximum speed, V_a the average speed, and A the cross sectional area of the water channel. This method was found to be sufficiently accurate for these small streams, providing suitably uniform sections of the stream were selected for measurement, and a sufficient number of timings taken.

Spraying was carried out on the evening of June 27, the temperature of the water at this time was 58°F. Details of the spraying procedure are given elsewhere (McDuffie et al); it is sufficient to mention here that the material used was 5 per cent solution of DDT in fuel oil, and that this was put down at a mean concentration of 0.26 lbs. DDT per acre. The population of blackfly larvae was re-checked on the afternoon of June 28, and on July 21, and August 7. No living eggs, larvae, or pupae of any species of blackfly were found anywhere in the treated length of the first stream at any of these examinations. Untreated portions of the stream, and similar untreated streams in the same vicinity, continued to harbour immature stages until

at least August 7. In the treated length of the second stream, the only larvae found at the examination on June 28 were at station 5, where there were two or three half grown larvae per plant, on grasses rooted in the centre of the stream. This station was very near to the upstream limit of the treated length, so that the exposure time was very short indeed, and the insecticide probably not well distributed. At the later examinations, which were made after the upper reaches of the stream had also been treated, no living eggs, larvae or pupae were found.

The results of these observations, together with those on all streams treated in 1947 are summarised in table 5, and the locations of all treated streams, including those treated in 1948, are shown on the map in figure 35. DDT concentration in streams treated from the air was estimated on the assumption that all the material falling on the surface of the stream was carried along in it, as follows:

Concentration in parts per million =

$$\frac{\text{Deposit in lbs. per acre} \times 10^6}{4840 \times 9 \times \text{Mean depth in feet} \times 62.5}$$

In the range of exposure time given, the minimum time represents the theoretical time for the water which received the spray to flow past the highest upstream observation station; the maximum time relates likewise to the furthest downstream station. In stream 1 the highest station was about half way between the limits of the sprayed length, so that here the minimum exposure time was quite high.

Aerial spraying experiment (2):

The second aerial spray plot covered half a mile of stream no. 2 from the source downwards. This was checked over

for blackfly larval population on the morning of June 30, immediately before the spraying, when 4 stations, each with a heavy to very heavy larval population were marked out. The temperature of the stream water was 55°F. The same insecticidal material was used in spraying this plot, but the deposit was 0.48 lbs. DDT per acre; details of the spraying are given elsewhere (McDuffie et al). The stream was re-examined on the same afternoon about three hours after the end of the spraying, when the water temperature was 63°F. Only a very few sick looking larvae were found, less than 1 per cent of the previous population, all of them near the origin of the stream in a poorly defined area largely under water. Many of these were hanging on silk. A further examination on the morning of July 1, water temperature 54°F., disclosed no living larvae at all, either in the treated stretch or below this. Subsequent examinations were made on the same dates as for stream no.1, and with the same results.

Scum, consisting of insects, spray material, and debris, which had accumulated on vegetation at the margins of the stream, was collected in water on the afternoon of the spraying, and preserved in alcohol for later examination. Detailed examination was carried out at Edmonton from August 20, to 30, 1947, when the condition of the material was found to be such that identification of most insects beyond the family was not practicable.

The groups of insects and other arthropods represented in this material, with the number of specimens of each obtained are as follows:

Other Arthropods:	
Araneae	23
Acarina	
Hydracaridae	13

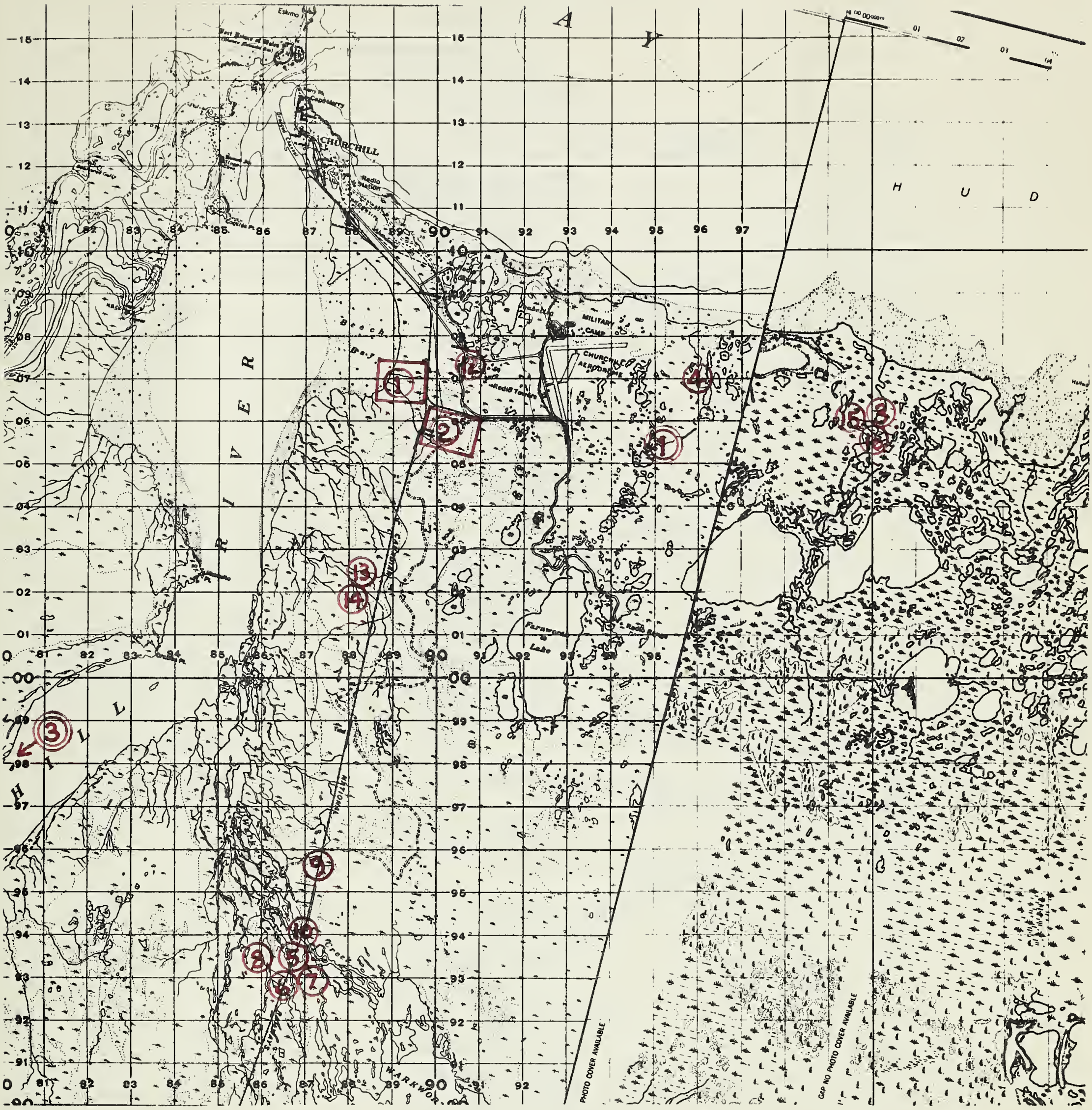


Figure 35: Map showing the location of Blackfly
breeding streams treated with
insecticides. Double circles, 1948
treatments. (No.2, 1948 = no.3 1947).

Insects:		
Apterygota		
Collembola		
Arthropleona (3 spp.)		223
Symphypleona		448
Exopterygota		
Plecoptera		
Nemouridae		
Nemoura spp.	nymphs	37
	adults	91
Thysanoptera		
Thripidae		8
Homoptera		
Aphidae		1
Chermidae	nymphs	5
	adults	2
Coccidae		
Steingelia sp.nov.		10
Endopterygota		
Coleoptera		
Carabidae		3
Elateridae		3
Dytiscidae	larvae	2
	adults	4
Chrysomelidae		2
Hydroscaphiidae		6
Trichoptera		
Limnophilidae		1
Diptera		
Nematocera		
Culicidae	Aedes spp. males	2
	females	8
Chironomidae	pupae	7
	adults	1504
Heliidae		16
Simuliidae	larvae	43
	adults	3
Mycetophilidae		53
Cecidomyidae		9
Scatopsidae		5
Brachycera		
Dolichopodidae		6
Empidae		13
Cyclorrhapha		
Lonchopteridae		2
Cordyluridae		2
Syrphidae		1
Phoridae		8
Chloropidae		5
Anthomyidae		4
Hymenoptera		
Chalastogastra		
Tenthredinidae		3
Cimbicidae		1

Clistogastra	
Ichneumonidae	2
Mymaridae	6
Proctotrupidae	4
Chalcidae	6
Cynipidae	2

This represents a total of some 2600 specimens belonging to 37 different families, of which only 56 specimens (representing 2 families) belong to species it was desired to control. Of the remainder, many are parasites and predators, some of them, in the families which are to be controlled; others are competitors with these. Although this was clearly not a strictly random sample, it serves to indicate how insignificant the objective result of such an operation may be in comparison with its total effect on the biocoenotic equilibrium.

The third aerial spraying operation, on the morning of July 3, put down a deposit of 0.26 lbs. DDT per acre on the half mile stretch of stream no.2, in between the portions treated in the first and second operations. As this stretch had been found to be without larvae two days previously, no further entomological observations were made on it at this time. In later surveys made on the other stretches of this stream, this stretch was found to be equally free of infestation.

Direct Application of Insecticides to Streams:

It had been intended to conduct these experiments primarily with emulsion formulations, as these appeared to be the logical preparations for this purpose. In view of the results obtained in the aerial spraying experiments with the cheaper and more readily obtained oil solutions, however, it was decided to concentrate on these, and to employ emulsions only

for the purpose of comparison.

The first step in the procedure adopted was the selection of a suitable stream for experimental treatment; the requirements are a high population of blackfly larvae, a well defined channel presenting a reasonable length without undue tributaries or distributaries, and suitable localities for flow measurement and insecticide application. Streams were surveyed in some detail, the amount of material needed to give the required concentration and time of exposure calculated approximately, and this amount applied if possible at the same time. Usually an observer would be present in the stream during the treatment, to watch the progress of the insecticide down the stream, and observe any immediate reactions of the blackfly larvae. In general the insecticide was applied a short distance from the upstream end of the surveyed length, in order to leave a portion of the stream undisturbed for check observations. The stream was then resurveyed as nearly as possible 24 hours after the treatment, and in most experiments, again when opportunity offered after another interval of about a week or more.

Fourteen streams were treated in all, using various concentrations and exposure periods with each of the insecticides listed in the introductory section. The results are summarised in table 5. In special instances, samples of animal life presumably killed by the treatment were collected on screens fixed in the stream below the treated stretch. Water samples were also taken from these streams for pH and salinity determinations. Detailed accounts of each stream treated follow:

Experiment 3: A substantial stream draining into Hudson Bay five

miles east of Churchill camp, shown on maps as Eastern Creek. It is a permanent stream, draining from an extensive area of lakes some three miles inland, and has a well defined bed of gravel and boulders. Throughout its length it flows through open tundra meadow, but there are patches of birch and willow near the mouth. The point selected for the application of insecticide was at the junction of two small tributaries from the west side, about a mile and a half stream length from the shore. The pre-treatment survey of this stream was made on July 10. Flow measurements were made at either end of the surveyed stretch, as a check on the accuracy of the method, and good agreement between readings was obtained. The water was somewhat alkaline, with a pH of 8.46, the salinity much lower than that in other streams sampled, at 56 p.p.m. chlorides, measured as sodium chloride. Six observation stations were marked out as follows:

1. 80 yards downstream from treatment point. Fine gravel bottom; deeper; slower current. Patches of larvae in lines at about 8 to the linear inch on stones.
2. 380 yards downstream. Coarse gravel bottom; dimensions and flow similar to treatment point. Very heavy larval population on stones at the bottom and on vegetation at stream margins.
3. 630 yards downstream. Island at eastern bank. Medium gravel bottom. 10 to 20 one-third grown larvae per linear inch on grasses.
4. 880 yards downstream. Mixed clay and gravel bottom; stream breaks up round several islands. Very heavy population, all stages from newly hatched larvae to pupae.
5. 1020 yards downstream. Boulders and very coarse gravel. Moderate population of half grown larvae on vegetation on the east side. Patchy heavy population on stones in centre.
6. 1410 yards downstream. Rapids; many very large boulders. Patches of larvae on vegetation at sides and rocks in centre. One-third to two-thirds grown.

Three species of *Eusimulium*, probably new species were present here in addition to *S. venustum*. Two 3 foot by 4 foot sampling screens with 16 meshes to the inch were fixed in

[illegible]

the stream, ten yards below station 6.

Treatment was with 10 per cent DDT in oil solution by means of a gravity dispenser contrived by C.N.Husman. This consisted of a 4 gallon drum fitted with a wheel valve laterally near the bottom, leading through five feet of 3/8" bore rubber tubing to a four foot length of 3/8" bore copper pipe, and was calibrated for discharge rate at various valve settings beforehand. This was arranged with the container on the bank of the stream, and the outlet of the copper pipe held in a wooden support 2 - 3" above the water surface. Treatment was done on the afternoon of July 11, and the oil spread, mixed in, and carried well, although a strong SE breeze resulted in some piling up of insecticide in bays on the west bank. The concentration was one part DDT in ten million parts of water for an application time of 30 minutes. After 25 minutes treatment, larvae were beginning to release from the vegetation about 50 yards downstream. Good turbulence immediately below the site of application was a primary factor in the good distribution obtained.

The stream was examined again 24 hours after the treatment; no attached or living larvae were found at any of the observation points or elsewhere in the treated stretch. Specimens of pupae were collected from the treated and untreated portions of the stream for rearing. The screens from the downstream end were collected and the material from them preserved in conjunction with that from experiment 4 for later examination. 58 per cent emergence was obtained from pupae from the treated portion, so that there was no definite evidence of toxicity to pupae. A final examination of the stream was made on July 24, 13 days after the

treatment, by which time some reinfestation had taken place. No pupae were found, but there was a very general light infestation composed of all stages up to two-third grown larvae, with a preponderance of very young larvae. Unlike the streams draining into the Churchill River, there had been no great reduction in flow.

Experiment 4: This was done in a smaller stream than the last, draining from a small lake into Hudson Bay about 2½ miles east of Churchill camp. There was more variation in the character of this stream, which ran in some places between high banks, and had some stretches of clay, and some of sandy bottom. There was rather more vegetation along the banks than at Eastern Creek, the pH of the water was similar at 8.35, but the salinity was much higher at 143 p.p.m. Surveys and treatment were made on the same days as for experiment 3, the following 5 observation stations being marked out over a length of half a mile:

1. S-bend, 160 yards below point of treatment: many pupae on vegetation and a few half grown larvae on stones. Coarse gravel bottom.
2. 260 yards downstream. Island in centre of stream. Some pupae on stones very few larvae. Boulders.
3. 360 yards downstream. Group of grassy islands in centre. Fine gravel and sandy bottom. Few larvae and pupae on vegetation.
4. 610 yards downstream. Rapids below small bay. Medium gravelly bottom. Many larvae on stones.
5. 820 yards downstream. Small rapids; medium gravel with boulders. Very few half grown larvae on vegetation, none on stones.

The larval population in this stream had decreased greatly from that observed on previous visits on June 25 and July 7. Two new species of Eusimulium were taken here. Flow measurements were taken at either end of the treated stretch, and a sampling screen was fixed 20 yards below station 5.

The same 10 per cent DDT in oil solution was used for treating this stream, but it was applied with an ordinary hand spray pump. Dosage and application time were the same at 0.1 p.p.m. for 30 minutes.

During the first half of the treatment the material was sprayed onto the surface of the stream, with the jet held a few inches above the surface. It was found that some of the finer mist was carried away by the high wind, so that the procedure was changed to spraying with the jet held under water. This method seemed to be entirely satisfactory.

No attached or living larvae were found on examination 24 hours after the treatment. Pupae and eggs from the treated and untreated parts of the stream, and material from the gauze screens were collected. Adult emergence from the untreated pupal material was 71 per cent, and from the treated material 47 per cent, giving a possible treatment mortality of 34 per cent. Eggs from the treated and untreated portions of the stream hatched uniformly with no detectable differences. The stream was examined again on July 25, when in spite of a greatly reduced flow, it was found to be liberally reinfested with all stages from egg to pupa. A final examination on August 11 showed the stream very swollen by recent rain, with only a few larvae, very few pupae, all within the upper 100 yards, and no eggs.

The material collected from the screens in experiments 3 and 4 was examined as follows:

The quantity of vegetable and inorganic debris mixed in with the specimens was such that it was necessary to remove all the larger fragments by hand for separate examination, and then to elutriate off the smaller particles, also for separate

examination. The quantity of material obtained was so great that complete counts were not practicable; a sample was taken by dispersing the specimens in alcohol in petri dishes, and making random complete counts on a number of fields of view under a binocular microscope. These counts were then added, and the material as a whole was scrutinized for the occurrence of organisms which did not show up in the sample counts. The results obtained by this method were as follows:

Totals in sample counts:

CRUSTACEA	
Branchiopoda	
Anostraca	
Branchinecta spp.	11
Cladocera	
* Eurycercus (glacialis?)	9
Daphnia spp.	15
Conchostraca	
Limnetis spp.	75
Copepoda	
* Heterocope septentrionalis	9
Malacostraca	
Amphipoda	
Gammarus spp.	3
ARACHNIDA	
Araneae	1
Hydracaridae	2
INSECTA	
Exopterygota	
Plecoptera	
Nemouridae	
Nemoura spp. nymphs	31
adults	7
Ephemerida nymphs	10
Homoptera	
Chermidae	2
Endopterygota	
Coleoptera	
Dytiscidae larvae	4
adults	3
Trichoptera larvae	
Hydropsychidae)	
Ryacophilidae)	10
Other families	16

Diptera		
Nematocera		
Chironomidae	larvae	11
	pupae	9
	adults	35
Simuliidae	larvae	903
	pupae	4
	adults	35
Mycetophilidae		3
Brachycera		
Empidae		2

(* It is reported that only one previous record of each of these species exists.)

Representatives of the following groups were also encountered in the general scrutiny: Collembola, Trichoptera adults, Elateridae, Tenthredinidae, Tipulidae, Anthomyidae, and Mollusca - Pulmonata. With the possible exception of the beetles the material was not in good condition, and closer identifications could not be made.

Experiment 5: An appreciable proportion of the blackflies at Churchill breed in artificial drainage ditches of the type used in this and some of the succeeding trials. The turbulence in these channels is at all times rather less than in the streams, and late in the season is virtually absent. This channel was flowing very slowly indeed, but had a very heavy larval and pupal population for a surveyed length of 350 yards, the population decreasing thereafter. This length included a right angle bend under a railway culvert which provided ideal conditions for flow measurement, at a distance of 200 yards from the point of treatment. A sampling screen was fitted a further 200 yards downstream. This, and the streams in experiments 6 to 9 were all treated with insecticide on July 14. Treatment was again with 10 per cent DDT in fuel oil, applied to give a concentration of

TABLE 5 - Summary of Data from Insecticidal Treatment of Streams

Exp. No.	Date of Treatment	Observed Treated Length of Stream (Yards)	Average Flow in Cusecs	Insecticide Formulation	Method of Application	Concentration p.p.m.	Application Time (Minutes)	Dosage* (p.p.m./min.)	LARVAL POPULATION		
									Before Treatment	24 Hours After Treatment	Subsequently
1.	June 27	900	12.20	5% DDT in fuel oil	Aerial spray	0.095	15 to 30	1.425 to 2.85	Heavy	Nil	Nil for at least 41 days
2.	June 30	2500	10.00	5% DDT in fuel oil	Aerial spray	0.150	0 to 60	0 to 9.00	Heavy	Nil	Nil for at least 41 days
3.	July 11	1400	88.00	10% DDT in fuel oil	Gravity dispenser	0.100	30	3.00	Heavy all stages	Nil	Reinfested with young larvae in 14 days
4.	July 11	850	6.70	10% DDT in fuel oil	Hand sprayer	0.100	30	3.00	Moderate	Nil	Reinfested with all stages in 14 days
5.	July 14	250	0.57	10% DDT in fuel oil	Medicine dropper	0.590	15	8.85	Heavy and mature	Nil after first 100 yd.	---------
6.	July 14	85	1.98	Fuel oil	Medicine dropper	1.680	15	25.20	Heavy all stages	Almost unchanged	---------
7.	July 14	300	6.30	10% chlordane in fuel oil	Medicine dropper	0.079	15	1.185	Heavy all stages	Some control for 100 yd.	Remained infested
8.	July 14	600	120.00	50% DDT wettable powder	Portable press. sprayer	0.075	20	1.50	Very heavy	Few first 350 yd., nil beyond	---------
9.	July 14	400	1.97	10% DDT in fuel oil	Medicine dropper	0.126	5	0.63	Heavy all stages	Slight reduction	Remained infested
10.	July 15	4400	270.00	10% DDT in fuel oil	2 pressure sprayers	0.176	15	2.64	Very heavy	Nil after first 100 yd.	---------
11.	July 18	250	0.57	25% DDT emulsion	Medicine dropper	0.490	15	7.35	Heavy	One living larva found	---------
12.	July 20	80	0.87	5% gamma-BHC emulsion	Graduate and paddle	0.100	15	1.50	Very heavy and mature	About 50% reduction	Remained infested
13.	July 21	650	0.54	P.P.B.(Pyrenone) emulsion T.143	Graduate and paddle	0.500	15	7.50	Moderate and mature	Reduced for 150 yd. only	Remained infested
14.	July 21	1500	1.62	25% DDT emulsion	Graduate and paddle	0.100	15	1.50	Moderate all stages	Nil	Nil for at least 10 days
15.	July 24	20 120	8.20 17.50	5% gamma-BHC emulsion	Graduate and paddle	0.190 0.089	15	2.85 and 1.335	Heavy Heavy	Few living About half	Remained infested Remained infested
16.	July 24	100	13.60	25% chlorinated camphene emulsion	Graduate	0.164	15	2.46	Very heavy	No change	Remained infested

* See explanation in Introduction.

about one part DDT in two million parts of water for a period of 15 minutes only. As the dosage required for this was only three ounces, this was applied by medicine dropper, and timed by stop watch. Pupae were collected from various situations in the stream before and after the treatment. The oil spread well, and moved slowly through the first part of the stream, more rapidly, and with better mixing further downstream.

A preliminary examination at six hours after treatment, and the regular 24 hour examination both indicated that the kill of larvae was incomplete for the first hundred yards below the point of treatment, but complete thereafter throughout the surveyed length. Adult emergences were 21 per cent from the untreated pupae, and 48 per cent from the treated pupae, so that there was no evidence of pupal mortality due to the treatment. The screen was removed at the 24 hour survey, and the material collected from it was examined collectively with that from screens out of other drainage channels, the results are given under experiment 9.

Experiment 6: This was done in a drainage channel very similar to the previous one, and with a very similar blackfly population, but for a distance of less than 100 yards only. There was a very heavy growth of shrubs along the banks, and the flow was rather greater than in no.5.

The treatment of this channel was with fuel oil alone, for purposes of comparison with the results with insecticide solutions in fuel oil. This was applied by medicine dropper immediately after the survey was made, to give a concentration of one part of fuel oil to about 600,000 parts of water, for a

period of 15 minutes. The behaviour of the material in the channel was similar to that of the insecticide in the previous trial. Pupae were collected before and after the treatment.

A very slight and local release of larvae occurred just below the point of application, during the actual treatment; the situation after 24 hours was unchanged from this. Pupal emergence from the untreated sample was 51 per cent, and from the treated sample 54 per cent.

Experiment 7: This was done in a small tributary stream, flowing from Warkworth Creek into Goose River. There was great variation in width, the stream flowing through a small pool, and fanning out into a number of separate beds at its efflux into Goose River. The bed consisted of gravel, stones, and boulders, and the banks were rather open and grassy, but with spruce, larch, and dwarf willow growing a little back from them. There was a brisk flow, which was conveniently measured at the railway culvert, from which the insecticide was applied.

For about 100 yards downstream from the culvert, the blackfly larval and pupal population was heavy, though somewhat localized; beyond this the population was sparser.

This stream was treated by medicine dropper with 10 per cent solution of Chlordane in fuel oil. The concentration used was about one part Chlordane in ten million parts of water for an application time of 15 minutes. Samples of pupae were collected before treatment and 24 hours after this. Good turbulence at the railway culvert aided distribution of the insecticide, which seemed to pass satisfactorily through the pool, and could be seen in the stream on the other side of this.

Figure 36: Goose River, treated in experiment 8, 1947.

Figure.37: Herriot Creek, treated in 1948.

Some larvae could be seen to be releasing their hold on vegetation at the conclusion of the treatment for a distance of 50 yards below the culvert. The stream was resurveyed 24 hours after treatment, when there was a noticeable reduction in the larval population near the point of treatment, although this did not extend very far, and even above the pool it was no longer perceptible. Percentage figures for pupal emergences were not obtained from this stream, but a high proportion of emergences was obtained from both treated and untreated batches.

Experiment 8: This involved the treatment of Goose River itself (Fig. 36) at a point a little below the bridge on which the Churchill Railway crosses it. This is a substantial river, with a flow at the time of treatment of some 120 cusecs; unfortunately it was not possible to survey this to any great distance below the point of treatment, partly on account of inaccessibility, and partly because it breaks up into a maze of secondary streams, some of which were, however, encountered in the survey after experiment 10. There are small rapids immediately below the treatment point, and throughout the observed distance, the bottom is of large stones and boulders, with patches of moderate growth of filamentous algae and some higher plants.

Stones and vegetation bore a heavy population of larvae, mostly nearing maturity, together with many pupae and some eggs. Samples of pupae were taken from just below the application point, and from 600 yards downstream.

Treatment was with a water suspension of a 50 per cent DDT wettable powder, applied by a Dobbins portable pressure sprayer, the operator wading back and forth in the stream.

The concentration used was about one part DDT in thirteen million parts of water, applied for 20 minutes. During this time there was an interval of 5 minutes for pumping up the sprayer. The insecticide was applied on the morning of July 14, the operator making four double crossings of the river.

The 24 hour survey of this river revealed a very considerable reduction in the larval population, only a few scattered living larvae were found, from the line of application to a distance of 350 yards downstream. Beyond this distance, pupae only were found to a total distance of at least 500 yards. Substantial emergence of adults was obtained from both treated and untreated pupae.

Experiment 9: This was done in a drainage channel, similar to those used in experiments 5 and 6, with very little flow, and practically no turbulence. Flow estimates were made at the railway culvert, where the insecticide was applied also.

There was a heavy population of all stages of larvae and of pupae for a surveyed distance of 400 yards below the treatment point. *Simulium venustum* was the dominant species here, but *Eusimulium latipes* was also present. A sampling screen was used here.

A still further reduced dosage was applied here in an attempt to discover what the marginal dosage would be. Three-quarters of an ounce of 10 per cent DDT solution was applied over a period of five minutes, giving a concentration of about one part DDT in eight million parts of water.

On resurveying after 24 hours there was found to be only a slight reduction in the numbers of larvae near the

point of application. The reduction increased further downstream to a maximum of about 50 per cent from 75 yards onwards. Most of the treated pupae which were taken from this stream gave rise to adults.

The material collected from the sampling screen in this experiment was examined collectively with that from experiments 5 and 6. The procedure adopted in examining this material was the same as that described under experiment 4, except that the number of animal specimens obtained was so small that there was no difficulty in removing and counting every specimen. This was probably partly because of the much slower current and the greater proportion of vegetable matter suspended in the water, screens becoming choked with this material, and hence inoperative, before many specimens had been caught. The much smaller variety of species obtained is interesting:

CRUSTACEA		
Malacostraca		
Gammarus sp.		1
Conchostraca		
Limnetis spp.		3
INSECTA		
Exopterygota		
Plecoptera		1
Ephemerida	nymphs	17
	adults	5
Endopterygota		
Trichoptera	larvae	1
	adults	2
Diptera		
Nematocera		
Chironomidae	larvae	3
	pupae	2
	adults	2
Simuliidae	larvae	10
	pupae	6
	adults	3
Tipulidae		1
Brachycera		
Empidae		3

<u>Experiment 10</u>: This experiment was carried out on Warkworth Creek, which, with a flow of about 270 cusecs, was the largest river treated. Flow measurements and treatment were both made from the only convenient location, the Churchill Railway bridge. In view of the size of the river, a somewhat more accurate method was employed for measuring flow, applying Simpson's Rule, and using the bridge piers as ordinates. The bottom of Warkworth Creek is covered with large boulders, and there is moderate vegetation. The Creek breaks up into a number of streams, unites with Goose River, flows through a fair sized lake, and again breaks up into streams, before finally emptying into the Churchill River some five miles below the bridge from which it was treated.

A full survey of the population of blackflies was not made before the treatment; some two hundred yards of the river, above and below the bridge ,had been under observation for some days. There was an abundant population of pupae and larvae, the latter mostly between maturity and half growth, on rocks and vegetation wherever the flow was adequate.

The flow estimate was made and treatment was carried out between eight and nine o'clock on the evening of July 15. $2\frac{3}{4}$ imperial gallons of a 10 per cent DDT solution were applied over a period of 15 minutes. Application was made by two operators with portable pressure sprayers, walking back and forth along the railway bridge, and directing the spray down at the water surface. Each operator worked from one half of the bridge.

There was a slight loss of material, carried by wind, and deposited on the bridge structure. The calculated concentration was about one part DDT in six million parts of water.

24 hours after treatment a few larvae were still found on rocks to a distance of about 100 yards from the bridge. Beyond this, the main channels of the river were examined thoroughly to a distance of 2½ miles. For part of this distance the water is mixed with that from Goose River (experiment 8). No larvae of any description were found beyond 100 yards from the bridge. Pupae were collected from 1½ and 2 miles downstream, and gave adult emergences of 55 and 80 per cent respectively. Many fish, including suckers up to 18" in length were seen, a good catch of jackfish was made at the bridge by a fishing expedition two days later, and no complaints of dead fish or reduced yield were made by the trapper who keeps his dogs on the fish from fish traps about 200 yards upstream from the bridge.

Experiment 11: This experiment involved a second treatment on the drainage channel which was treated, but not disinfested, on July 14 (experiment 9). There was a heavy population before the treatment, consisting mainly of larvae.

Treatment was with a 25 per cent DDT emulsion concentrate, applied by medicine dropper to give a concentration of about one part DDT in two million parts of water for a period of 15 minutes. Treatment was done at nine o'clock on the morning of July 18; examination at five o'clock on the evening of July 19 disclosed a single living larva below the treatment site, a heavy population remaining above.

Experiment 12: The stream used in this experiment drains from the Isabelle Lake system in a southwesterly direction, and is controlled by a sluice gate and weir. The bed of the stream is well defined for a length of about 80 yards only, thereafter the water fans out into a grassy marsh. The stream was shallow at the time of treatment, with a coarse gravel bottom, the margins and the bed itself becoming more grassy proceeding downstream. Earlier in the season, this stream harboured as large a population of blackfly larvae as was to be found anywhere close to the camp, but this population was well past its peak at the time of treatment. Flow was measured at the sluice gate. Pupae for rearing were taken before and after treatment, and the pupae used in experiment 17 were collected later, from the top of this stream.

A benzene hexachloride emulsion concentrate containing 5 per cent gamma isomer was applied at a point 20 yards below the sluice gate on the afternoon of July 20. The emulsion was diluted to four times its volume with stream water, and was applied by dribbling it in from a graduate at the rate half and ounce per minute for 15 minutes. The calculated concentration was one part gamma BHC in ten million parts of water. In view of the small length of stream available for observations, the insecticide was mixed in just below the point of application with a paddle.

Towards the end of the treatment larvae could be seen beginning to let go, and a few minutes later, large numbers of them were trailing on silks from their points of attachment. Examination after 24 hours, however, revealed at least 50 per

cent of the larvae of all ages still present, alive and active; water temperature was 62°F. The percentage adult emergences from the treated and untreated pupal samples were 12 and 82 per cent respectively, so that there is evidence of considerable pupal mortality due to this treatment. Further examinations of this stream on July 28 and August 6, showed that the population developed normally.

<u>Experiment 13</u>: This stream was not treated until July 21, by which time lack of rain had left but little water in most of the streams, and correspondingly small blackfly populations. This stream flows through the area of heavy birch and willow shrub growth adjoining the tidal flats on the east bank of the Churchill River. A point of junction with a second stream was selected as suitable for the application of insecticide,and 650 yards length of the stream below this point was surveyed. The bottom was largely mud with scattered stones; the banks with a very heavy growth of shrubs. Flow was measured in each of the tributaries separately and added, the main stream offering no length suitable for measurements.

The larval population was evaluated on the basis of observations at 20 stations; at most of these there was a moderate to heavy population of rather mature larvae.

Pyrenone emulsion concentrate was applied by dribbling in from a graduate to give a concentration of one part piperonyl butoxide to two million parts of water for a period of fifteen minutes. This was mixed in with a paddle. The temperature of the stream water at the time of treatment was 61°F.

During the treatment, observations were made on larvae

at a point 50 yards below the application site, where the presence of the insecticide in the water could just be detected. Six minutes after the first arrival of treated water, larvae started to double up repeatedly, and the first larvae released after a further four minutes. By the end of the treatment the great majority of the larvae had released. At the resurvey 24 hours later however, there was found to be considerable infestation remaining in the stream. Only at the first three stations was there anything approaching effective control, the maximum reduction in larval population further downstream being less than 50 per cent. Specimens of treated and untreated pupae gave 46 and 50 per cent adult emergences respectively.

Experiment 14: This stream runs parallel to that treated in the previous experiment, and is very similar to it in character except that the upstream portion of it consists of a straight drainage channel, which provided very suitable conditions for measurements of flow. Vegetation on the banks was somewhat lighter, the bottom had more gravel and sand, the water was clearer, and the blackfly population rather heavier. Observations were made at 16 stations distributed over a length of 1500 yards.

A 25 per cent DDT emulsion concentrate was applied for fifteen minutes on the morning of July 21 to give a concentration of one part DDT to ten million parts of water. Application was by dribbling in from a graduate, and mixing with a paddle. The temperature of the water was 62°F.

The larval population at a point 50 yards below the treatment site was observed during the treatment, but the only reaction was the release of a very small proportion of the larvae

towards theend of the application. At the 24 hour examination no blackfly larvae, living or dead, could be found anywhere in the treated part of the stream; water temperature at this time had fallen to 55°F. Many other insect larvae, especially those of chironomids and ephemerids, were seen living and apparently unaffected by the treatment. Treated and untreated pupal blackfly samples gave emergences of 60 and 64 per cent respectively. A final examination on July 31 showed the treated stretch still without larvae or pupae, these two stages being present in about equal numbers in the untreated length of the stream.

Experiment 15: This experiment, and the succeeding one, were done in a portion of Eastern Creek upstream from that utilized in experiment 3. The conditions of terrain and stream bottom were similar to those in experiment 3, but as these streams were tributaries which unite to form the main stream of Eastern Creek, width and flow were less, although the depth was about the same. In this experiment, a single application was used for observations on the effect of two different concentrations by treating a short distance above the influx of a tributary, flow rates being measured both for the main stream and for the tributary.

Infestation before treatment was heavy, and consisted almost entirely of larvae on stones. Vegetation was very scanty, and although empty pupal cases were quite numerous, no living pupae were found.

Treatment was with 5 per cent gamma, BHC emulsion concentrate, to give concentrations of one part in five million

and one part in ten million, above and below the tributary influx respectively. Application was by dribbling from a graduate and mixing in with a paddle, the application period being 15 minutes. The temperature of the stream water was 63°F.

The treated stretch was resurveyed on the afternoon of the following day. In the 20 yard length above the junction (i.e. at the higher dosage), a few living larvae remained attached to the rocks. Below the junction, the reduction in population was less than 50 per cent.

Experiment 16: This stream was another of the upper tributaries of Eastern Creek, similar in character to that used in the previous experiment. The larval population was rather heavier, but again no living pupae were found. A hundred yard length of the tributary wassurveyed, and a situation with good turbulence was found for the application of the insecticide. The material used for treatment was a 25 per cent Toxaphene emulsion concentrate; this was diluted with stream water, and applied by dribbling in from a graduate to give a concentration of about one part in six million over a period of 15 minutes. This application imparted a distinct milkiness to the stream water, but no release of larvae during the application could be seen to occur. Treatment was done on the morning of July 24, and the stream was re-examined on the afternoon of July 25. No change in the larval population could then be detected.

Laboratory Experiments with pupal Blackflies:

Experiments were performed in the laboratory to investigate the effects of the five toxicants employed in the

[illegible]

[illegible]

[illegible]

[illegible]

stream treatments on the pupal stage of S. venustum. An attempt was also made to obtain some information on the time-concentration relationship for a fixed blackfly pupal mortality, with a given toxicant of proved practical value.

Experiment 17: A large batch of pupae in cocoons attached to grasses was collected from the stream used in experiment 12 at 2.0 p.m. on July 18, and water for the preparation of insecticide dispersions was collected at the same time and place. The temperature of the water was 60°F., pH was 8.4 and salinity 130 p.p.m.

Dispersions of the insecticides were prepared in the following concentrations, expressed as parts per million. Gamma BHC: 0.02, 0.04, 0.08, 0.16, 0.32, 0.64, 1.28 and 2.56; DDT, chlorinated camphene, and Chlordane: 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4, and 12.8; pyrethrum-piperonyl butoxide (P.P.B.), based on piperonyl butoxide content: 0.5, 1.0, 2.0, 4.0, 8.0, 16.0, 32.0, and 64.0. One check container of plain stream water was used for each batch of dispersions.

Batches of twenty pupae retained in their cocoons on vegetation were then immersed, each for one minute, one batch in each of the above dispersions, including the check containers of plain water. The batches immersed in the insecticides were rinsed briefly in water from the same stream before setting them aside for emergence in covered jars containing a little moist cotton wool. During immersion the specimens were kept moving slowly through the liquid to simulate the effects of stream flow. The treatments were commenced at 4.0 p.m. on July 18 with 0.02 p.p.m. gamma-BHC, and continued with increasing concentrations

of this material, followed in sequence by DDT, chlorinated camphene, P.P.B., and Chlordane, each in increasing concentration. Treatment was completed at 8.10 on the same evening. During the treatment, most of the larvae present on the vegetation were washed off into the treating fluid and were allowed to remain there, at least ten larvae of varying size in each vessel. Observations at 9.0 a.m. on the next day showed some of the larvae to be still living in the following containers:

All containers of plain stream water.
Gamma-BHC: 0.02, and 0.04 p.p.m.
DDT: 0.1, 0.2, and 0.4, p.p.m.
Chlorinated camphene: 0.1, 0.2, and 0.4 p.p.m.
P.P.B.: none.
Chlordane: 0.1, 0.2, 0.4, 0.8, and 6.4 p.p.m.

Records of adult emergence were made on July 19 and 22, and a final count was made on July 23. In a few batches a conspicuous fungus growth developed and emergence was much less than anticipated, but apart from this there was good correlation between concentration and mortality, and emergence in the controls was very uniform. The results obtained are set out in table 6, and the graphical expression of these results in figure 38 indicates L.D. 50's for gamma-BHC and chlorinated camphene of 0.15 and 1.9 p.p.m./minutes respectively. The mortality given by DDT, P.P.B., and Chlordane was too erratic for reliable interpretation, and was not sufficient at any concentration to compare favourably with that given by the above two materials.

These results indicate the desirability of investigating the relationship between exposure time and concentration for a given mortality for gamma-BHC. Attempts to do this were unsuccessful on account of a dwindling pupal population.

TABLE 6. The number of adult blackflies emerging from 20 pupae after one minute immersion in various toxicant dispersions.

Concentration in parts per million	0.0 (check)	0.5	1.0	2.0	4.0	8.0	16.0	32.0	64.0
P.P.B.	16	5*	12	15	12	11	5	3	2
Concentration in parts per million	0.0 (check)	0.1	0.2	0.4	0.8	1.6	3.2	6.4	12.8
DDT	5*	10	13	13	14	14	10	13	10
Chlorinated camphene	16	15	14	14	9	8	7	6	4
Chlordane	15	8*	9	15	10	5	8	6	11
Concentration in parts per million	0.0 (check)	0.02	0.04	0.08	0.16	0.32	0.64	1.28	2.56
Gamma-BHC	17	13	13	14	12	5	3	1	0

* Results upset by fungous growth on pupae.

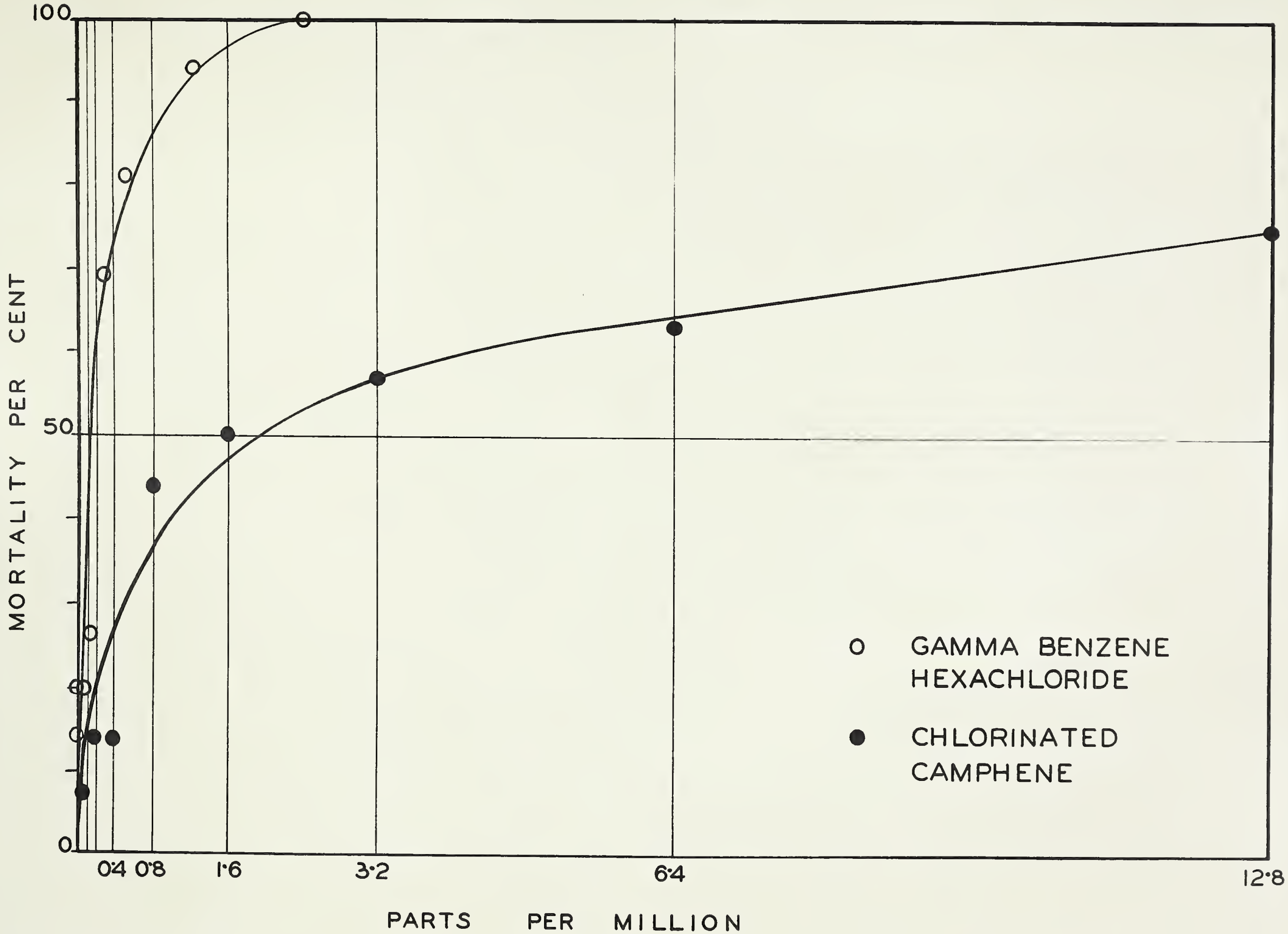

100
50
0
MORTALITY PER CENT
0·4 0·8
1·6
3·2
6·4
12·8
PARTS PER MILLION
o GAMMA BENZENE HEXACHLORIDE
● CHLORINATED CAMPHENE

FIGURE 38

Discussion: There has been some controversy as to whether DDT and other insecticides actually kill the blackfly larvae in treated streams, or whether they merely cause them to release their hold, possibly to reattach further downstream, where the concentration may be reduced by the junction of tributaries and the influx of drainage water. In the Churchill locality, the opportunities for re-attachment are slight, and may only present themselves to larvae in streams draining into the Churchill River. The evidence from this work however, is that the larvae are actually killed; certainly no living larvae were removed from any sampling screens, and since the exposure period for released larvae moving downstream in the treated water would be greater than that for those caught on the screens or remaining attached, it is unlikely that any of them survive.

The duration of treatment has been recorded as application period and not as exposure period, since the latter naturally increases with the distance from the application site. The concentration, likewise, is that theoretically obtaining at the application site; this figure undergoes a corresponding decrease as the distance from the point of application increases. At any given point downstream, the concentration increases gradually to the maximum, and decreases again more gradually from the maximum to zero, the rate of both the increase and the decrease being less at greater distances downstream. There is no evidence that these factors have any appreciable influence on the mortality obtained for a distance of at least several miles downstream.

The susceptibility of blackfly larvae to DDT appears

remarkable, until it is recalled that as a contact insecticide this material normally has access to the tarsi, or at least to restricted areas of the body only, whereas the whole of the integument of the blackfly larva is exposed to DDT.

The application of DDT in oil solution from the air at 0.25 lbs DDT per acre immediately before the first blackfly pupae are formed, will effectively control for the season the common arctic species of blackfly breeding in the area sprayed, in streams up to $1\frac{1}{2}$ feet in mean depth. Heavier dosages might be required for deeper streams. It would seem likely, that with suitable delivery rates, a single swath applied along the course of smaller streams, and a swath along either bank with the shore line as swath centre for the larger streams, would prove equally effective, and this would be a very practicable procedure.

Such a procedure, however, would involve greater expense and, judging from the variety of insects killed, a far greater interference with the balance of nature, than the more laborious procedure of direct application to the streams. Until the effects of this interference are more fully understood, it seems desirable that the aerial method be employed in special circumstances only. Similar mortality in diverse groups of insects has previously been shown to occur as a result of aerial spraying operations in Panama (2). Direct application to streams of DDT in oil solutions to give one part in ten million for 15 minutes caused remarkably little interference with other life, but is somewhat more arduous and might have to be repeated, the first treatment being given immediately before the start of pupation, and the second two or three weeks later. Rarely is

there an opportunity to control an economically important insect by using such an efficient, naturally provided, means of distributing and insecticide as the flow of a stream. Advantage should be taken of this opportunity. If further studies confirm that gamma-BHC is an effective pupicide, it might be possible to avoid a second treatment by applying a mixture of DDT and gamma-BHC just before the emergence of the first adults. This would increase the cost of materials, but would reduce the labour cost and would interfere less with the normal life of the stream.

The greater residual effect of treatment from the air appears to be due primarily to the continued infiltration of a very small concentration of DDT into the stream, washed off rocks, the soil, and to some extent vegetation by rain and by drainage water. Mortality of adults during and after the spraying operation may be a contributary factor. A further possibility is that, as Prèvost maintains, adult blackflies return to the stream in which they matured to lay their eggs (43); the streams treated from the air were the only ones which had produced no pupae prior to treatment. However, the reinfestation of these streams in July 1948, suggests that this tendency is not manifest, at least in the earliest generation.

Some development of equipment is required for routine direct application stream treatments. The requirements are, a simple form of current meter to enable a ready and reasonably accurate estimate of flow to be made, and a suitable dispenser. The latter should consist of a stock tank to hold perhaps ten gallons of material, leading to a flow meter consisting of a differential pressure gauge and a variable orifice, controlled

by a wheel valve. The dispenser should be calibrated to give the required flow of insecticide at each setting for a concentration of one part DDT in ten million parts of water, using a ten per cent solution of DDT in fuel oil. The whole apparatus should be designed to fit on a folding tripod stand which could be set up in a small stream, on the bank, or in a boat. Two men with this equipment and a paddle, stopwatch, measuring stick and tape, could treat streams with a flow up to 250 cusecs rapidly and conveniently, and the problem would by reduced to the ever present problem of transportation. A shallow draught boat with outboard motor would assist here, and the motor could be employed also to secure good distribution of insecticide, taking the place of a paddle in the larger streams.

What previous evidence there is seems to suggest that the direct effects of DDT on animals other than insects in ponds and tidewater are unlikely to be serious (59), even at concentrations of one part DDT in three million parts water, with exposure time limited only by the stability of the compound. Observations during this work do not entirely support this view; the possibility of accumulated concentrations of DDT in lakes fed by repeatedly treated streams should not be lost sight of. Indirect results can also be serious; blackfly larvae for example, form a significant food item of fish, especially suckers, which are themselves important food of sled dogs.

<u>1948 work with Insecticides against immature stages of Blackflies</u>:

The much drier conditions in 1948, and the earlier use of considerable areas of country for experimental spraying with

[illegible]

[illegible]

[illegible]

[illegible]

DDT from the air prevented extensive work with insecticides in streams. The results obtained with DDT in 1947, were however confirmed by applications to Eastern Creek, using the same stretch of the creek again, and to Herriot Creek (708885), flowing into the Churchill River from the west, some 25 miles south of Churchill. In 1948 flow measurements were made with a Gurley flow meter; the method used in 1947 was checked against this meter, and gave figures agreeing within 5 per cent.

A preliminary test of a wettable powder containing 15 per cent "Parathion" (o,o-diethyl o-p-nitrophenyl thiophosphate) was made, and both this material and gamma BHC were tested for toxicity to blackfly eggs. Results obtained in these tests are summarised in tables 7 and 8.

The stream used in the first experiment has its origin at 951054 and drains into a small lake on the tundra east of Churchill camp. The water temperature at the time of treatment was 62°F and the pH 7.5. Since this was a new toxic material a sampling screen was used; an analysis of a portion of the material from this screen is as follows:

MOLLUSCA		
Gastropoda		
Pulmonata		3
ARACHNIDA		
Acarina		
Hydracaridae		3
CRUSTACEA		
Branchiopoda		59
Copepoda		22
INSECTA		
Apterygota		
Collembola - Arthropleona		8
Exopterygota		
Plecoptera		
Nemouridae	nymphs	87
Ephemerida	nymphs	21
Hemiptera		
Corixidae	nymphs	1

TABLE 7. Summary of data from insecticidal treatment of streams. 1948

Experiment No. and date of treatment	Observed treated length of stream in yards.	Average flow in cusecs	Insecticide formulation	Method of application	Concentration p.p.m.	Application time -- mins	Dosage* (p.p.m./mins.)	Larval population	
								Before treatment	24 hours after treatment.
1.July 7	200	0.62	15% Parathion wettable powder	Medicine dropper	0.2	15	3	Moderate	Nil
2.July 22	1400	30.8	10% DDT in fuel oil	Graduate	0.113	15	1.7	Moderate	Nil
3.July 24	5300	141	10% DDT in fuel oil	Graduate	0.0695	15	1.04	Light	Nil

* See explanation in Introduction to 5.1.3.

TABLE 8. The ovicidal properties of Parathion and Gamma benzene hexachloride.

Insecticide	Concen-tration p.p.m.	Exposure period minutes	Dosage p.p.m./ mins.	Per cent hatch
Parathion	0.2	15	3.0	80
	0.5	15	7.5	2
	1.0	15	15.0	0.3
Gamma-BHC	0.2	15	3.0	83
	0.5	15	7.5	15
	1.0	15	15.0	4
Check (untreated) 1.	-	-	-	88
2.	-	-	-	99.5

Endopterygota		
Coleoptera		
Dytiscidae		3
Trichoptera	larvae	2
Diptera		
Nematocera		
Chironomidae	larvae	5
	pupae	3
	adults	2
Heliidae		
Culicoides sp.		2
Tipulidae		1
Culicidae		
Aedes sp.		1
Simuliidae	larvae	323
	pupae	5
Mycetophilidae		2

In so far as it was possible to decide on a field examination, the crustacean material was all alive at the time of collection, 24 hours after treatment; the insect material however, was dead. Adults emerged from 67 per cent of pupae collected before treatment, as compared with 25 per cent from pupae collected immediately after treatment, and 20 per cent from pupae collected 24 hours later, so that "Parathion" appears to have appreciable toxicity to pupae.

The second and third experiments confirmed the effectiveness against larvae of DDT at 1.5 p.p.m./minutes. The length under observation in Herriot Creek (FIG.37) was greater than that in any 1947 test.

Both gamma-BHC and "Parathion" especially, appear to have useful ovicidal properties against blackflies. The L.D. 50's for these materials are of the order of 4 and 6 p.p.m./minutes respectively.

A few tests against caged fish of insecticides suitable for blackfly control were made in 1948. Neither jackfish, suckers, nor sticklebacks were permanently affected

by dosages of DDT up to 300 p.p.m./minutes, although jackfish especially became violently agitated after about six minutes at the higher concentrations, and many were unconscious at the end of the exposure. Suckers withstood 15 minutes in "Parathion" at 1 part in 100,000.

Discussion: "Parathion", by virtue of its apparent toxicity to both eggs and pupae, and apparent harmlessness to stream crustacea, would appear to offer advantages over DDT. Its cost however is greater, and it is believed to be much more toxic to man.

5.2. Protection of the Person from Biting Fly Attack.

It is clear from the results set out in 5.1, that the possibility of economical routine control of the numbers of *Aedes* mosquitoes, at least of the migratory species (reputedly, *A. nigripes*, *A. nearcticus*, and *A. campestris*) by chemical means is not very great. Even with DDT, to ensure freedom from mosquitoes in a single locality would require an annual spraying of an area of the order of at least a thousand square miles (say a circle of 20 miles radius), an operation which would cost about a million dollars. As far as tabanids are concerned, the chemical approach is even less encouraging, and it is only against blackflies that this method seems at all hopeful.

The information available relative to the second approach

to biting fly control is indicated in sections 1 to 3; it is quite inadequate, as yet, for any but the most tentative suggestions as to how this might possibly be initiated.

By elimination, there remains for consideration only the third approach.

5.2.1. Repellents:

Although very great improvements in repellents for biting flies have been made in the last few years by the application of routine test methods on a very large number of materials, further significant progress cannot be expected without more fundamental work on the factors which attract biting flies to their hosts, and on the mode of action of repellents.

In 1947 a study was made of the relative effectiveness of four standard insect repellents, twelve other liquid repellents, and two repellent creams. Primarily, the study was against _Aedes_ mosquitoes, but the abundance of blackflies in the areas used for tests, allowed simultaneous tests against these insects. Accepted standard methods of test were employed.

Of the standard repellents, dimethyl phthalate afforded the longest protection against both mosquitoes and blackflies, averaging 381 minutes and 393 minutes respectively. Repellent mixture 6-2-2, which contains 6 parts dimethyl phthalate, 2 parts Rutgers 612 (2-ethyl-1,3-hexanediol), and 2 parts Indalone (_n_-butyl mesityl oxide oxalate), was

only slightly inferior to dimethyl phthalate in protection time. Rutgers 612 afforded less protection against mosquitoes than any other standard material, and repellent N.M.R.I. 448 (30% 2-cyclohexyl cyclohexanol, 70% 2 phenyl cyclohexanol) gave good protection against mosquitoes, but afforded less protection against blackflies than any other standard.

Of the remaining materials, only n-propyl N,N-diethyl succinamate afforded a protection time greater than that given by dimethyl phthalate. It is doubtful whether the improvement is sufficient to justify the adoption of this material, should it prove sufficiently non-toxic.

All materials in use suffer from the considerable drawback of being plasticisers, softening and dissolving plastics, paints, and varnishes. Some of the inconvenience of this could be avoided by eliminating these materials and finishes as far as possible on equipment such as axe and other tool handles, pencils, etc. which are regularly handled in the open.

All observations made on repellents used while working in the field agree in respect of two general conclusions. These are, firstly, that there is little apparent difference in the effectiveness of the four standard repellents tested here, under conditions of actual use; and secondly, that with a heavy and aggressive population of mosquitoes, and normal activity of the subject in field work, the best of the repellents may require renewal at least as often as once every hour. Under very severe conditions; perspiration, working in water or through heavy vegetation, the period of adequate protection may of course be further reduced. The application of repellent

by hand to the outside of the clothing, particularly across the shoulders, round the waist, and on the seat of the trousers has material protective value.

The application of repellent in the field is awkward; both hands are required, and if the bottle is set down, such is the distraction of the biting fly attack that it is forgotten with surprising frequency. The use of a liquid soap dispenser for insect repellent was introduced by Mr. J. Myler of the Edmonton City Parks Department, and proved very successful in Golf clubs and Ball grounds in Edmonton during 1948. This method could well be adopted in permanent military camps, such dispensers being mounted at the outside doors of buildings, and kept filled during the fly season.

Attempts to find repellents which can be administered orally are not, as yet, promising; this idea was first recommended by Ochman in 1911 (68), but little work has been done on these lines until quite recently.

The term repellent is an unfortunate one, implying as it does, an action at a distance which these materials do not, in fact, exhibit. Modern repellents are gustatory rather than olfactory in their action; this fact, and the resulting necessity for the application of a thin continuous film needs to be pointed out to inexperienced users.

5.2.2. Protective Clothing and Shelters:

Many insects attacking man, are less inclined to do so through clothing of non-animal origin, and this appears to

apply to mosquitoes; many observers have recorded that biting is worse through woollen fabrics than through cotton of similar texture.

Extensive tests have been carried out with materials of cotton and artificial fibres, mainly against Aedes aegypti and very satisfactory materials are known (3). These materials are however mostly expensive and often uncomfortable to wear. Annand et al (4) have found that coarse open mesh materials worn underneath garments of highly permeable fabric prevent the biting of A. aegypti in the laboratory. Field trials of string vests, which are normal military issue in winter were made during 1948, and worn under ordinary cotton twill shirts gave complete protection under very severe conditions. This arrangement proved much more comfortable than closely woven materials. In this 'distance piece' type of clothing, the thickness of the open mesh material should, of course, be comparable with the proboscis length of the mosquitoes concerned. A. nigripes has the longest proboscis of the Churchill Aedes with 0.42 cm.

In general, the looser the clothing the less it is bitten through; biting through is worst whenever and wherever the cloth is stretched tightly over the skin.

Gjullin (23) has shown for several species of Aedes that biting is worse through dark coloured materials than it is through light coloured, and states that colours are chosen on the basis of their spectral reflectances. Observations in section 3.1.3 would seem to suggest that it may be spectral absorption and consequently surface temperature which is the deciding factor, rather than reflectance. Whatever the reason,

lighter colours are certainly to be preferred.

Blackflies and tabanids do not bite through clothing; but the former are very active and persistent in their efforts to gain an entrance to the space between clothing and body. Carefully designed closures are necessary to prevent this.

Properly designed clothing should reduce the psychological as well as the physiological effects of biting flies; that is, in addition to preventing biting, it should obviate the necessity for the 'removal reaction', and should minimise the impact of insects, at least on the face. The use of a fly fringe - eye length in front and shoulder length behind - in place of a net, might have advantages by virtue of its greater mobility, in reducing the need for removal reaction at less sacrifice of comfort and vision. Such a device would also be less inclined to get caught in vegetation, and would suffer less if it did so; the principle seems to be embodied in the improvised headgear of some of the Churchill residents.

The impact of insects can only be eliminated by wearing a head net, and if necessary, arm nets. It seems reasonable to suggest that if a net has to be worn it might as well be one which will exclude everything, including blackflies and (possibly) no-see-ums, but cost is presumably a factor here. Certainly, the comfort advantages of a wide mesh net do not more than outweigh the necessity for keeping it doped with repellent, and the inconvenience of the occasional blackfly penetration. There may be some advantage in a net held sufficiently clear of the face to enable the eyes to focus on it, and hence also on any insects which may alight on it. Arm nets have few advantages and many disadvantages as compared with sleeves.

The fly-proof shelter is a much neglected means of providing relief from the attentions of biting flies; it is the only single measure which will eliminate completely all the elements of the biting fly attack. The psychological effects respond to the provision of such a shelter as they will to no other treatment.

Arctic biting flies in general are out-of-door insects; they do not congregate in large numbers, even in relatively unprotected buildings, nor do they cause such serious discomforts when they are inside them. Accordingly it should not prove difficult to render tents and shelters for use in the field sufficiently fly proof for practical purposes, nor to design and produce a special 'fly-refuge' for the use of field parties. Such a structure should be light, quickly and simply erected, and have plenty of headroom; a double door entrance to enable users to get rid of their accompanying swarm of biting flies before entering the main chamber is an advantage. The roof as well as the walls should be of screening; a solid roof serves as a great attraction to tabanids. Perfectly serviceable temporary shelters have been improvised in the forest with no other materials than a roll of cheesecloth, an axe, and a packet of tacks, and have proved invaluable. The aerosol bomb as at present produced, is a ready and efficient, if somewhat expensive, method of clearing out such shelters when erected. The mere knowledge of the existence of such a refuge, supplemented possibly by the right to get into it for say, five or ten minutes in every hour and relax, with flies kept at a distance, is of very great value to men working in the field.

5.2.3. Other Aspects of Protection and Control:

Attempts have been made to immunise animals so that either mosquitoes will not feed on them, or that they will not react to bites received. Such attempts are unlikely to succeed until the factors which attract mosquitoes and the causative agents of reaction to their bites are understood. Dubin et al (18) working with _Anopheles quadrimaculatus_ and rabbits succeeded only in sensitizing these.

With regard to the control of tabanids very little work has been done. Neither the 'pools of death' nor the carrying of black adhesive shields recommended by Porchinsky (77) can be regarded as very practicable in circumstances such as are encountered at Churchill. Traps as proposed by du Cordroy (66) and by Criddle (69) appear almost equally unpromising from the human viewpoint. A great deal more knowledge of these insects is needed.

When the irritation of the bites of flies interferes with sleep, some treatment is called for. Ammonia, washing soda, iodine, and various ointments containing local anasthetics are in common use. Any application for this purpose should have antiseptic properties to guard against secondary infection. Hoffman (70) recommends the local application of chloroform. Very hot water is an excellent counter irritant for blackfly bites.

Next perhaps, to attempting to bathe (which can always be postponed), the greatest discomfort from biting flies while.

living in the open, arises during defecation. Palliatives which have been found useful include a smudge fire immediately to windward, and an aerosol bomb, set to discharge slowly, in the same situation. Smudges, of course, are often impossible under operational conditions, and an aerosol bomb, though effective, is hardly economical. Certainly it is as well to disregard the dictates of modesty, and to choose an exposed windy situation.

It is felt that a big contribution to the solution of the psychological problem could be made through an indoctrination programme on the lines indicated by Shelesnyak (51). Superimposed on general arctic knowledge, should be some knowledge of and interest in biting flies, imparted through the normal media of training films, lectures, and popular literature and pamphlets. Such knowledge while presenting a true picture, should draw attention to the pleasanter aspects of the species concerned - the relative improbability of disease transmission, the acquired immunity resulting from bites, the small amount of blood taken, and so on. The more interesting gaps in our knowledge of these insects should also be presented: it is when the individual has nothing to do that the insect menace is greatest; if he has an interest in the biting fly problem, he will never have nothing to do when there are flies about. The contributions to knowledge from such mass amateur observations would probably be small, but the contributions to morale might be very great. Above all else, the importance of controlling the removal reaction should be stressed; there are physiological (47) as well as psychological grounds for this

recommendation. Philip (42) has stated that interruption in feeding results in regurgitation of blood from the mesenteron into the oesophageal diverticula, a statement which has since been confirmed by the work of Marshall and Staley (36) and of Lumsden (34). This suggests the possibility that such interruption may also result in the regurgitation of the contents of the diverticula into the puncture.

In conclusion it may be stated that the psychological threat of the biting fly can be greatly mitigated by the simple cultivation of an attitude of patient tolerance; by learning to accept these insects as an essential feature (at least for the present) of an environment which, after all, offers many compensations in other directions. Getting used to these pests and 'learning to live with them' should be an essential part of the training of all personnel for the north, since it is certain that despite aeroplanes and DDT, and anything else that these may immediately foreshadow, under operational conditions at least, the biting fly will be an inseparable feature of life in the north for many years to come.

6. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

6.1. Summary of Control Conclusions.

Chemical insecticides offer no immediate economic control of mosquitoes or tabanids. In special circumstances such as a military emergency, when economic considerations may be secondary, the application of DDT from the air at 0.5 lbs per acre will effect control of mosquito larvae. Adult mosquitoes will also be controlled, but infiltration into the sprayed area will be rapid.

Economic chemical control will require the development of insecticides of markedly greater toxicity per unit weight, or more probably, of more economical methods of distribution. The latter may be achieved through the development of aerosol generators with output of a new order of magnitude.

Blackflies may be controlled by the procedure for mosquito larvae, or more safely and economically, by the application of DDT in any form to streams, to give 1.5 p.p.m/minutes, just before the beginning of pupation. A second dose 2 to 3 weeks later may be required. "Parathion" and gamma-BHC offer possibilities for use against eggs and pupae.

There are no immediate prospects of control of any of the three groups being secured through ecological means.

The most immediately hopeful approach is through

protection of the individual and his immediate habitats. This has two aspects; psychological, through training and cultivation of a reasonable attitude to biting flies; physiological, through the use of good repellents such as dimethyl phthalate, proper protective clothing, and shelters in conjunction with local insecticides.

6.2. Recommendations for Further Work.

A major result of most research is to demonstrate the limitations of existing knowledge: some of the more outstanding lacunae in this field are given briefly here.

The development of insecticides and distribution methods are not mentioned; the biting fly problem alone hardly justifies the expense entailed in this work, and the results obtained are so generally applied that the work will, in any event, continue.

Except where indicated, work on all of these problems could proceed simultaneously.

1. The factors affecting the hatching of mosquito eggs, especially chemical factors.

2. The feeding habits of adult mosquitoes, other than on the blood of man, and the relationship of these to ovulation and oviposition, and to flight habits and migration.

3. The food materials, feeding habits and behaviour of larval blackflies. Mating habits, flight habits, and feeding habits other than on human blood, of the adults.

4. Life histories, and especially larval behaviour and feeding habits of the commoner species of tabanids.

5. The nature of the effect of biting flies on large bodies of men, living in the open, and the relative importance of psychological and physiological effects. Also, the effect of such bodies of men on the biting flies; is more men going to mean more blood meals, more eggs, and hence more flies ?

6. The sensory physiology of all biting flies, especially mosquitoes and blackflies, with particular reference to the attraction of these insects to their hosts.

7. The nature of the toxic materials injected by biting flies, especially blackflies, and the possibility of combating these.

8. The mode of action of repellents, and the development of better repellent chemicals. (After some progress has been made on 5.)

9. The design, testing, and development of protective clothing.

REFERENCES

1. Abdel-Malek, A. Plant hormones as a factor in the hatching of A. trivittatus eggs. Ann. Ent. Soc. Amer. 41: 51 - 57. 1948.

2. Annand, P.N. et al. Insects killed by DDT aerial spraying in Panama. Natl. Res. Coun. Insect Control Comm. Report No. 108. 1945.

3. Annand, P.N., E.R.McGovran, and J.Lipton. Mosquito resistance of 12 fabrics, JO cloths, Byrd cloth, and Oxford (Pepperell) cotton cloth. OSRD Insect Control Comm. Report No. 12. Jan. 1945.

4. Annand, P.N., J.P.Linduska, and F.A.Morton. Laboratory and field tests on the permeability of fabrics to biting by mosquitoes. OSRD Insect Control Comm. Rept. No. 29. June 1945.

5. Anon. Churchill Harbour Board Records.

6. Anon. Normal mean daily max. and min. temp. (Prairie Provinces) Met. Serv. Can. Monthly maps.

7. Bailey, N.S. A mass collection and population survey technique for larvae of Tabanidae. Bull. Brook. Ent. Soc. 43: 22 - 29. 1948.

8\.

References No. 8 and 32 deleted for security reasons.

9. de Boissezon, P. Expériences au sujet de la maturation des oeufs chez les culicidés. Bull. Soc. Path. Exot. 22: 683 - 689. 1929.

10. Brescia, F. Salt marsh and anophéline mosquito control by ground dispersal of DDT aerosols. Jour. Econ. Ent. 39: 689 - 715. 1946.

11. Brescia, F. and I.B.Wilson. Larvicidal treatment of large areas by ground dispersal of DDT aerosols. Jour. Econ. Ent. 40: 309 - 313. 1947.

12. Bruck, C. Über das Gift der Stechmücke. Deut. Med. Wochenschr. 1787 - 1790. 1911.

13. Cameron, A.E. Bionomics of the Tabanidae of the Canadian prairie. Bull. Ent. Res. 17: 1 - 42. 1926.

14. Chitty, H. and D.Chitty. Canadian Arctic wild life enquiry. 1942-3. Jour. Anim. Ecol. 14: 37 - 45. 1945.

15. Clark, A.J. The mode of action of drugs on cells. pp. 72 - 94. Arnold, London. 1933.

16. Cornwall, J.W. and W.S.Patton. Some observations on the salivary secretion of the commoner bloodsucking insects and ticks. Ind. Jour. Med. Res. 2: 509 - 593. 1914.

17. David, W.A.L. and P.Bracey. Factors influencing the interaction of insecticidal mists and flying insects. Parts 2 and 3. Bull. Ent. Res. 37: 1 - 27, and 177 - 190. 1946.

18. Dubin, I.N., J.D.Reese, and L.A.Seamans. Attempt to produce protection against mosquitoes by active immunization. Jour. Immunol. 58: 293 - 297. 1948.

19. Fairchild, G.B. Trials of DDT as a larvicide against Simulium. OSRD. Insect Control Comm. Rept. No. 98. 1945.

20. Fairchild, G.B. and E.A.Barreda. DDT as a larvicide against Simulium. Jour. Econ. Ent. 38: 694 - 699. 1945.

21. Fallis, A.M. Observations on Leucocytozoon infections in birds receiving paludrine, atebrine and sulphamerazine. Can. Jour. Res. D. 26: 73 - 76. 1948.

22. Garnham, P.C.C. and J.P.McMahon. The eradication of Simulium neavei Roubaud from an oncocerciasis area in Kenya colony. Bull. Ent. Res. 37: 619 - 628. 1947.

23. Gjullin, C.M. Effect of clothing color on the rate of attack of Aedes mosquitoes. Jour. Econ. Ent. 40: 326 - 327. 1947.

24. Glasgow, R.D. Control of blackflies. Jour. Econ. Ent. 32: 882 - 883. 1939.

25. Glasgow, R.D. and D.L.Collins. The thermal aerosol fog generator for large scale application of DDT and other insecticides. Jour. Econ. Ent. 39: 227 - 235. 1946.

26. Hearle, E. Notes on the more important mosquitoes of western Canada. Proc. 19th Ann. Meet. N.J. Mosq. Exterm. Assoc. 7 - 14. 1932.

27. Hearle, E. The life history of Aedes flavescens Müller. Trans. Roy. Soc. Can. 3rd Ser. 23.5. 85 - 101. 1929.

28. Hecht, O. Arch. für Schiffs und Tropen Hygiene. 32: 561. 1928.

29. Hine, J.S. Habits and life histories of some flies of the family Tabanidae. U.S.D.A. Bur. Ent. Tech. Ser. No. 12. 1906.

30. Huff, C.G. Ovulation requirements of Culex pipiens Linn. Biol. Bull. 56: 347 - 350. 1929.

31. Imms, A.D. A general text-book of entomology. p. 619. Methuen and Co. London. 1936.

32. a serious livestock pest in Saskatchewan. Sci. Agr. 27: 428 - 445. 1947.

33. Latta, R. Field experiments with heat generated aerosols. Jour. Econ. Ent. 39: 614 - 619. 1946.

34. Lumsden, W.H.R. Observations on the effect of microclimate on biting by Aedes aegypti. Jour. Exp. Biol. 24: 361 - 373. 1947.

35. Macloskie, G. The poison apparatus of the mosquito. Amer. Nat. 22: 1888.

36. Marshall, J.F. and J. Staley. On the distribution of air in the oesophageal diverticula and intestine of mosquitoes; its relation to emergence, feeding, and hypopygial rotation. Parasit. 24: 368. 1932.

37. Matheson, R. Handbook of the mosquitoes of North America. p. 44. 2nd Ed. Comstock Publ. Co. Inc. Ithaca. 1944.

38. McClure, H.E. Aspection in the biotic communities of the Churchill area, Manitoba. Ecol. Monogr. 13: 3 - 35. 1943.

39. McKinley, E.B. The salivary gland poison of Aedes aegypti. Proc. Soc. Exper. Biol. and Med. 26: 806. 1929.

40. Mellanby, K. The activity of certain arctic insects at low temperatures. Jour. Anim. Ecol. 9: 296 - 301. 1940.

41. Patton, W.S. and A.M.Evans. Insects, ticks, mites, and venomous animals of medical and veterinary importance. pp. 140, 150. Liverpool School of Trop. Med. 1929.

42. Philip, C.B. Possibility of mechanical transmission by insects in experimental yellow fever. Ann. Trop. Med. Parasit. 24: 493. 1930.

43. Prévost, G. Eradication of blackfly larvae for a long term by the use of DDT at a critical time. Mimeogr. Montreal, Dec 29. 1947.

44. Prévost, G. Directions for using DDT in plaster in the eradication of blackfly larvae. Mimeogr. Montreal, April 8. 1948.

45. Raup, H.M. The pollinization of Habenaria obtusata. Rhodora 32: 88 - 89. 1930.

46. Rempel, J.G. and A.P.Arnason. An account of three successive outbreaks of the blackfly Simulium arcticum, a serious livestock pest in Saskatchewan. Sci. Agr. 27: 428 - 445. 1947.

47. Riley, W.A. and O.A.Johannsen. Medical entomology. pp. 221 - 224. McGraw-Hill, New York. 1938.

48. Roy, D.N. The physiology and function of the oesophageal diverticula and of the salivary glands in mosquitoes. Indian Jour. Med. Res. 14: 995 - 1004. 1927.

49. Schaudinn, F. Arb. aus dem kais Gesundheitsamte. 20: 387. 1904.

50. Sen, S.K. A preliminary note on the role of blood in ovulation in Culicidae. Indian Jour. Med. Res. 4: 729 - 753. 1917.

51. Shelesnyak, M.C. Some problems of human ecology in polar regions. Science, 106: 405 - 409. 1947.

52. Shelford, V.E. and A.C.Twomey. Tundra animal communities of Churchill, Manitoba. Ecol. 22: 47 - 69. 1941.

53. Starling, E.H. Principles of human physiology. p.773, 9th Ed. Lea and Febiger, Philadelphia 1945.

54. Starling, E.H. Ibid. pp. 470 and 477.

55. Steward, J.S. Application of Gammexane to arthropods of veterinary importance. Nature, 158: 636 - 637. 1946.

56. Stone, A. Bionomics of Tabanidae. Ann. Ent. Soc. Amer. 23: 261 - 304. 1930.

57. Strickland, E. H. Unpublished communication.

58. Symes, C.B. and A.B.Hadaway. Initial experiments in the use of DDT against mosquitoes in British Guiana. Bull. Ent. Res. 37: 399 - 430. 1947.

59. Tiller, R.E. and E.N.Cory. Effects of DDT on some tidewater aquatic animals. Jour. Econ. Ent. 40: 431 - 433. 1947.

60. Twinn, C.R. The blackflies of eastern Canada. Can. Jour. Res. D. 14: 97 - 150. 1936.

61. Twinn, C.R., B.Hocking., W.C.McDuffie., and H.F.Cross. A preliminary report on the biting flies at Churchill, Manitoba. Can. Jour. Res. D. (to be published shortly.)

62. Wesenberg - Lund, C. Contributions to the biology of the Danish Culicidae. D. Kgl. Danske Vidensk. Selsk. Skrifte, Nat. Math. Afd., 8 Raekke. 7: 1 - 120. 1921.

63. Wigglesworth, V.B. The principles of insect physiology. p. 83. Methuen and Co., London, 1939.

64. Wright, S. Applied physiology. p. 320. 7th Ed. O.U.P. 1940.

Supplementary References:

65. Cantrell, W. and H.B.Jordan. New mosquito hosts for Plasmodium gallinaceum. Jour. Parasit. 31: 55 - 56. 1945.

66. Cordroy, M.R.L.Bourgault du. Trap for the destruction of cattle flies. Jour. Roy. Army Med. Corps 54: 208 - 211. 1930.

67. Gjullin, C.M., W.W.Yates and H.H.Stage. The effect of certain chemicals on the hatching of mosquito eggs. Science 89: 539 - 540. 1939.

68. Graybill, H.W. Repellents for protecting animals from the attacks of flies. U.S.D.A. Bull. 131. 1914. Abstr. in Rev. App. Ent. (B) 3: 37. 1915.

69. Hearle, E. Insects and allied parasites injurious to livestock and poultry in Canada. Can. Dept. Agr. Pubn. 604. p. 24. Ottawa 1938.

70. Hoffman, W.A. The effect of chloroform on some insect bites. Science 94: 66. 1941.

71. Hunter, W.D. An unusual invasion of A. sollicitans in Louisiana. Jour. Econ. Ent. 3: 504. 1910.

72. Longstaff, T.G. An ecological reconnaissance in West Greenland. Jour. Anim. Ecol. 1: 119 - 142. 1932.

73. O'Kane, W.C. Blackflies in New Hampshire. New Hampshire Agr. Exp. Sta. Bull. 32. 1926. Abstr. in R.A.E. (B) 15: 193. 1927.

74. Olin, G. The occurrence and mode of transmission of Tularaemia in Sweden. Abstr. in R.A.E. (B) 32: 56. 1944.

75. O'Roke, E.C. The incidence, pathogenicity, and transmission of Leucocytozoon anatis of ducks. Abstr. in Jour. Parasit. 17: 112. 1930.

76. Parker, R.R. Recent studies of tick borne diseases made at the U.S. Public Health Service at Hamilton, Montana. Proc. Pan. Pac. Sci. Congr. 5: 3367 - 3374. 1933.

77. Porchinsky, L. Tabanidae and the simplest methods of destroying them. Abstr. in R.A.E.(B) 3: 195. 1915.

78. Roubaud, E. L'éclosion de l'oeuf et les stimulants d'éclosion chez le Stegomyia de la fièvre jaune. Abstr. in R.A.E.(B) 15: 161. 1927.

79. Roubaud, E. and J.Colas-Belcour. Nouvelles recherches sur l'évolution expérimentale de Dirofilaria immitis chez quelques culicidés indigènes. Abstr. in R.A.E.(B) 25: 250. 1937.

80. Rubtzov, I.A. Investigations on the use of mineral oil emulsions for the control of blackflies. Abstr. in R.A.E.(B) 33: 186. 1945.

81. Sanderson, E.D. Controlling blackfly in the White Mountains. Jour. Econ. Ent. 3: 27. 1910.

82. Scott, J.W. Experimental transmission of swamp fever or infectious anaemia by means of insects. Jour. Am. Vet. Med. Assoc. 9: 448 - 454. 1920.

83. Thienemann, A. Die Stechmückenplage im hohen Norden. Abstr. in R.A.E.(B) 27: 128. 1939.

84. Waterston, J. On the mosquitoes of Macedonia. Bull. Ent. Res. 9: 1 - 12. 1918.

85. Yen, C. Studies on Dirofilaria immitis Leidy. Jour. Parasit. 24: 192 - 205. 1938.

SELECTED BIBLIOGRAPHY

1. Beattie, M.V.F. Physico-chemical factors in relation to mosquito prevalence in ponds. Jour. Ecol. 18: 67 - 80. 1930.

2. Blanchard, R. Les moustiques. Histoire naturelle et médicale. F. R. de Rudeval, Paris 1905.

3. Brennan, J.M. The Pangoniinae of neartic America. Bull. Univ. Kansas. 36: 249 - 401. 1935.

4. Dunn, M.B. Methods of protection from mosquitoes, black-flies and similar pests of the forest. Can. Dept. Agr. Pam. 55 n.s. 1925.

5. Dyar, H.G. The mosquitoes of Canada. Trans. Roy. Can. Inst. 13: 71 - 120. 1921.

6. Dyar, H.G. The mosquitoes collected by the Canadian arctic expedition, 1913 -18. Rep. Can. Arc. Exp. III Pt. C. 31 - 33. 1919.

7. Dyar, H.G. and R.C.Shannon. The north american two-winged flies of the family Simuliidae. Proc. U.S. Nat. Mus. 69: 54 pp. 1927.

8. Edwards, F.W. On the British species of Simulium. Bull. Ent. Res. 6: 23 - 42 and 11: 211 - 246. 1915, 1920.

9. Edwards, F.W., H.Oldroyd, and J.Smart. British blood-sucking flies. Brit. Mus. Nat. Hist. London, 1939.

10. Gjullin, C.M. A key to the Aedes females of America north of Mexico. Proc. Ent. Soc. Wash. 48: 215 - 236. 1946.

11. Headlee, T.J. The mosquitoes of New Jersey and their control. N. J. Agr. Exp. Sta. Bull. 348. 1921.

12. Herms, W.B. and H.F.Gray. Mosquito control. The Commonwealth Fund. New York, 1944.

13. Hindle, E. Flies in relation to disease; blood-sucking flies. Cambridge, 1914.

14. Hinman, E.H. A study of the food of mosquito larvae. Amer. Jour. Hyg. 12: 238 - 270. 1930.

15. Hinman, E.H. Mosquitoes in relation to human welfare. Ann. Ent. Soc. Amer. 25: 613 - 623. 1932.

16. Hinman, E.H. Predators of the Culicidae. Jour. Trop. Med. and Hyg. 37: 129 - 134, 145 - 150. 1934.

17. Howard, L.O. A remedy for gadflies. Porchinski's recent discovery in Russia, with some American observations. U.S.D.A. Div. Ent. Bull. 20 n.s. 1899.

18. Howard, L.O., H.G.Dyar, and F. Knab. The mosquitoes of North and Central America. Carnegie Institute, 1912 -17.

19. Howland, L.J. Bionomical investigation of English mosquito larvae with special reference to their algal food. Jour. Ecol. 18: 81 - 125. 1930.

20. Johannsen, O.A. Aquatic nematocerous diptera. N. Y. State Mus. Bull. 68 and 86.

21. Kellogg, V.L. Food of larvae of Simulium and Blepharocera. Psyche. 9: 166 - 167. 1901.

22. Mail, G.A. The mosquitoes of Montana. Mont. Agr. Exp. Sta. Bull. 288. 1934.

23. Marchand, W. The early stages of Tabanidae. Monogr. Rockfeller Inst. Med. Res. 13. 1920.

24. Marshall, J.H. The British mosquitoes. Oxford Univ. Press 1938.

25. Miall, L.C. The natural history of aquatic insects. Macmillan and Co., London, 1895.

26. Needham, J.G. and P.R.Needham. Guide to the study of fresh water biology. Amer. Viewpoint Soc. N.Y. 1927.

27. Philip, C.B. Methods of collecting and rearing the immature stages of Tabanidae. Jour. Parasit. 14: 243 - 253. 1928.

28. Philip, C.B. A catalogue of the blood-sucking fly family Tabanidae of the neartic region north of Mexico. Amer. Midland Nat. 37: 257 - 324. 1947.

29. Polunin, N. Botany of the Canadian eastern arctic. Nat. Mus. Bull. 92. Pt. I. Ottawa, 1940.

30. Reaumur, R.A.F.de. Mémoires pour servir à l'histoire des insectes. Histoire des cousins. 4: 573 - 636 1938.

31. Rempel, J.G., W.A.Riddell, and E.M.McNelly. Multiple feeding habits of Saskatchewan mosquitoes. Can. Jour. Res. E. 24: 71 - 78. 1946.

32. Smart, J. Insects of medical importance. Brit. Mus. Nat. Hist. London, 1943.

33. Stone, A. The horseflies of the sub-family Tabaninae of the neartic region. U.S.D.A. Misc. Pub. 305. 1938.

34. Strickland, E.H. Some parasites of Simulium larvae and their effects on the development of the host. Biol. Bull. 21: 302 - 338. 1911.

35. Strickland, E.H. Some parasites of Simulium larvae and their possible economic value. Can. Ent. 45: 405 - 414. 1913.

36. Theobald, F.V. A monograph of the Culicidae. Brit. Mus. London, 1901-10.

37. Trager, W. On the nutritional requirements of mosquito larvae. Amer. Jour. Hyg. 22: 475 - 493. 1935.

38. Twinn, C.R. Notes on some parasites and predators of blackflies. Can. Ent. 71: 101 - 105. 1939.

39. Ward, H.B. and G.C.Whipple. Freshwater biology. John Wiley and Sons, New York, 1918.

40. Woodbury, E.N. Rearing insects affecting man and animals. In: Chemical control of insects. Ann. Assoc. for the Advancement of Sci. No. 20. 1943.

A P P E N D I X   A

Sight records of Birds and Mammals during the Fly Season at Churchill:

Birds:

Gaviidae

Common Looh   Gavia immer

Ardeidae

American bittern   Botaurus lentiginosus

Anatidae

Canada goose   Branta canadensis *
Pintail   Anas acuta tzitzihoa *
Lesser scaup duck   Aythya affinis
American golden eye   Glaucionetta clangula
Red-breasted merganser   Mergus serrator

Accipitriidae

Rough-legged hawk   Buteo lagopus

Tetraonidae

Willow ptarmigan   Lagopus lagopus *

Charadriidae

Semi-palmated plover   Charadrius hiaticula semipalmatus *
Golden plover   Pluvialis dominica dominica *

Scolopacidae

Hudsonian curlew   Numenius phaeopus hudsonicus *
Hudsonian godwit   Limosa hoemastica *
Wilson's snipe   Capella gallinago delicatula *

Phalaropodidae

Northern phalarope   Lobipes lobatus *
Red phalarope   Phalaropus fulicarius
Willet   Catotrophorus semipalmatus
Greater yellow legs   Totanus melanoleucus *
Least sandpiper   Erolia minutilla
Semi-palmated sandpiper   Ereunetes pusillus *
Stilt sandpiper   Micropalama himantopus

Stercorariidae

Parasitic jaeger   Stercorarius parasiticus

Laridae

Herring gull   Larus argentatus
Glaucous gull   Larus hyperboreus
Common tern   Sterna hirundo hirundo *
Arctic tern   Sterna paradisaea

Tytonidae

Snowy owl Nyctea scandiaca
Short eared owl Asio flammeus

Alaudidae

Horned lark Eremophila alpestris

Corvidae

Canada jay Perisoreus canadensis
Crow Corvus brachyrhynchos

Turdidae

Robin Turdus migratorius

Laniidae

Northern shrike Lanius excubitor borealis

Fringillidae

Snow bunting Plectrophenax nivalis nivalis
White crowned sparrow Zonotrichia leucophrys *
Eastern tree sparrow Spizella arborea arborea
Pine grosbeak Pinicola enucleator leucura
Lapland longspur Calcarius lapponicus lapponicus

(* Nesting)

Mammals:

Rodentia

Porcupine Erethizon dorsatum
Muskrat Ondatra zibethica
Collared lemming Dicrostonyx hudsonius
Muskeg meadow mouse Microtus drummondi
Varying hare Lepus americanus

Ungulata

Caribou Rangifer caribou

Cetacea

White whale Delphinapterus leucas

APPENDIX B

An Insecticide Dispenser for Blackfly breeding Streams:

The dispenser is required to deliver a 10 per cent solution of DDT in fuel oil at controllable rates to give a concentration of DDT equal to one part in ten million parts of the water of streams with flow rates up to about 250 cusecs. The maximum tolerance permissible in this dosage, in view of the possible danger to fish and other aquatic organisms is considered to be plus or minus 20 per cent. The most important sources of error when treating streams are in the adjustment of a dispenser to give the required dosage rate, and in the measurment of the flow of water in the stream. An accuracy within 10 per cent can readily be obtained in the latter, even without the help of a flow meter, so that a further error of plus or minus ten per cent is permissible in the discharge rate of a dispenser.

The projected dispenser will give at least the required accuracy at the low end of its range and increasingly greater accuracy at higher flow rates, so that the net risk will be considerably less than that indicated by this figure. At the same time any simpler design of dispenser, which could perhaps be produced more cheaply, would require correspondingly more skilled labour to operate and more time in operation.

The dispenser is designed for insecticidal fluids of viscosity 5.0 centipoises (the range of viscosity figures quoted for fuel oil used in the North is 2.4 to 7.2 centipoises at 50°F), but with the aid of a calibration chart and a range

of orifices it would operate successfully at any combination of temperature and intrinsic viscosity likely to be encountered. The only dimensions where accuracy is of importance are those of the tubing and of the orifices.

The container consists of a ten gallon drum with a lid fitted with a gasket (B) and held in place by a wing nut on a bolt welded to the centre of the base of the drum. An air vent is required and could be conveniently drilled in the bolt (A). The drum is fitted with three legs of $\frac{1}{2}$" M.S. rod splayed at about 20° and extending about 15" below the drum. About 3" above the ends of these legs, which are pointed, are 2" collars (E) which also serve as stops for 3' tubular extensions required for use in the deeper streams. The outlet pipe, of $\frac{1}{2}$" bore, is placed half way between two legs about an inch above the base, and a drain plug is fitted in the base opposite to this (F).

The outlet leads directly to the flow meter shown on sheet 2, which is inserted at (C) in the drawing on sheet 1. This consists of a threaded union to hold the interchangeable orifice plates (J), and a differential pressure gauge (G) connected in parallel and leading to a wheel valve (K). For routine use three orifices connected in parallel, each with its own stopcock, might be desirable (shown dotted (H)), since the range which can be obtained with a single orifice is only about 5 times, but for an experimental prototype, so long as the orifice plates can be readily interchanged by means of a knurled ring or wing nut connection, this is not necessary. The differential pressure gauge should give a full scale deflection with a pressure

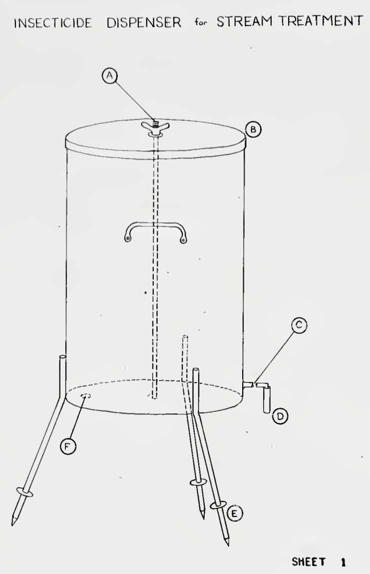


Figure 39.

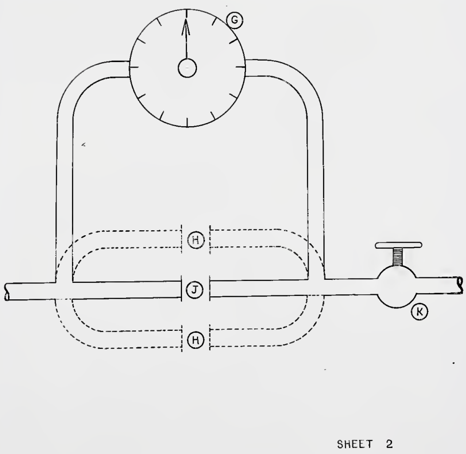


Figure 40.

difference equal to about 12" of water. It is understood that very suitable gauges are available in the form of war surplus air speed indicators for aircraft. The bore of the connecting pipes to this instrument would be determined by the fittings on the instrument; all other pipes should be of ½" bore, except that the final outlet should be arranged to discharge inside a short length of wider pipe of sufficient bore to allow at least 1/16" clearance all round the outlet (D). Four foot and six foot lengths of this wider pipe, each with one end cut off at 45° and a one foot length of oil resistant rubber coupling should also be provided.

The theoretical orifice diameters required in plates of 2 mm. thickness, determined from Poiseuille's equation are: low range (for streams 2 - 10 cusecs), 0.154 cms. medium range (10 - 50 cusecs), 0.23 cms. high range (50 - 250 cusecs), 0.344 cms., but for experimental purposes ten plates with aperture diameters in the range 0.1 to 0.5 cms. should be provided.

B29756